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AERONAUTICAL RESEARCH

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ADVANCED RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE AND ASTRONAUTICS
U.S. HOUSE OF REPRESENTATIVES

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AERONAUTICAL RESEARCH

MONDAY, DECEMBER 1, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met at 10 a.m., in room 2325, Rayburn House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The committee will be in order.

In opening these hearings on aeronautics I am very pleased this morning also to have present the chairman of the full Committee on Science and Astronautics, the Honorable George Miller of California. Good morning, Mr. Chairman.

Mr. MILLER. Good morning, Mr. Chairman.

Mr. HECHLER. In September and October of 1968, the Subcommittee on Advanced Research and Technology conducted 2 weeks of hearings on aeronautical research and development. In opening those hearings, I commented: "These hearings are designed to identify the priorities needed in aeronautical research and development. We are looking primarily toward the future in our emphasis on how to strengthen the entire area of aeronautics so that the Nation will be thereby strengthened in the 1970's and beyond."

The hearings which we are conducting this year are a continuation and extension of the 1968 hearings. They are an additional indication of the emphasis which the Committee on Science and Astronautics places on aeronautics.

The importance of significantly increased attention and support to aeronautical sciences and to the future problems of aviation capable of being solved by research and development is evident and, in many areas, critical. The dimensions of those problems are highlighted by the economics and capabilities of the aviation industry as they exist today. For instance, the value of the equipment operated by the air carriers today well exceeds $5 billion and their long-range financial indebtedness now being borne is about $6 billion. Air transport now accounts for more than 72 percent of the total passenger traffic miles traveled in the United States. We have over 118,000 aircraft and close to 600,000 nonmilitary airmen certificated in this country today. These statistics, staggering as they are, are really a sobering prediction of what we can expect over the next 10 years or more.

It is on that period of time that the subcommittee wishes to focus its interest. The lack of sound and long-range planning in the past, and the resulting failure to utilize, broadly and prudently, the technologies produced by research have resulted in the enormous difficulties being experienced by the aviation industry.

The Committee on Science and Astronautics, almost since its inception, has strongly advocated the utilization of our advanced research resources to provide for the contingencies in aeronautics and aviation as best they could be predicted. This subcommittee, year after year, during the hearings on NASA authorizations, has obtained the approval of the full committee for increased funding of NASA's aeronautical research program. It is thoroughly recognized that the leadership and prestige this Nation now enjoys in aviation is seriously threatened by operating conditions rapidly becoming intolerable, not to overlook the growing competence of our international competitors.

Thus, it is the intention of the subcommittee, during these hearings, to again help focus the attention of the Nation's leadership, both in the Federal and local governments, on the urgency of greater emphasis on aeronautical research. All sections of the Nation must be concerned because all, to some degree, are involved. We need more research attention directed to vertical and short takeoff and landing aircraft, to avionics, to innovative navigation systems, aircraft structures, materials, and noise suppression. We need to learn more about how industry can help through research into computers, data processing, and communications techniques. The list could go on and on.

In addition to urging more emphasis on aeronautical research and technology, this subcommittee intends to urge the early establishment of priorities that will build a great reservoir of scientific knowledge in aeronautics which will be available and applicable when it will be needed. We can no longer afford to solve today's problems with yesterday's technologies. Only advanced research can give us at least the opportunity to solve future problems with research products that are realistic and workable.

Our purpose today is primarily to discuss which of the many paths open to aeronautical R. & D. appears to match our future needs. Secondarily we are interested in discussions on how we are to achieve the goals we identify. The order in which I place these purposes is based on the observation that if one first decides were he wants to go, he can usually find someone to take him there.

We see that the pace at which areonautics develops is a matter of rising importance to the strength of our Nation. We also recognize that pace alone, is not enough. We must also establish our course. Of the many paths open to future development, the important ones are those which will best meet the challenges of the future environment, those which will best serve the needs of our evolving society, yet at the same time remain compatible with it. We must examine research and development goals in the context that aeronautics must adequately fulfill its function as a socioeconomic and political force of major importance.

The impact of aeronautics on our Nation and on our global society over the past two decades is dramatic. Those areas we once called independent geographic regions have vanished. Self-sufficient nations are also a part of the past. The art of flight has drawn the world together and whether we like our close neighbors or not, the effect is not reversible. To the contrary, the effects of aeronautical technology on the way our world functions will become even greater with time. This is an enviable position for a technology. It is enviable because it provides a view of the future in which the world's societies can accept

nothing less than the rapid growth and improvement in all aspects of aeronautical products and services.

This committee looks at this prospect of great growth and development with enthusiasm but also with deep concern. These bright prospects are predicated on the rising world requirements for aeronautical products and services. However, the number of participants in the aeronautical community, competitors if you will, is also rising. This bright period, as it applies to the aeronautical future of any nation, including our own, is neither automatic nor inevitable.

We can share it only if we plan for it.

One or two major studies per year over the past 30 years have examined the future of aeronautics. Many of them were ordered by Presidents who recognized that the future of aeronautics and the future of the Nation were inextricably related. It is regrettable that most of these studies fell sadly short of their intent. Although the studies all predicted growth, nearly all looked toward the future but could not see beyond the present.

Most commonly, the projections for future aeronautics and its requirements used the formula which says that if one aspirin works today, we will need 10 aspirins per day by the end of the decade. We may, indeed, need more aspirin tablets.

In a letter to the subcommittee last year, the then Executive Secretary of the National Aeronautics and Space Council, E. C. Welsh observed: "We need and we need now an antibiotic for the virus of postponing research and development."

But whatever course we take the R. & D. which pays off will be that which anticipates the operating conditions of tomorrow's environment and seeks systems which can provide the service expected, yet remain compatible with the environment being served.

It is a great official honor and personal pleasure for me to welcome the Executive Secretary of the National Aeronautics and Space Council, Mr. William A. Anders. We are fortunate, indeed, to have a man with the practical experience of Mr. Anders as the leadoff witness in this most important area of aeronautics.

STATEMENT OF HON. WILLIAM A. ANDERS, EXECUTIVE SECRETARY, NATIONAL AERONAUTICS AND SPACE COUNCIL; ACCOMPANIED BY MR. JOHN H. ENDERS AND LT. COL. DAVID D. YOUNG

Mr. ANDERS. Thank you, Mr. Chairman. Before I read my statement, Mr. Chairman, I would like to introduce two of my colleagues I have with me this morning, Mr. John Enders, who is on loan to the National Aeronautics and Space Council staff by the NASA. Mr. Enders has an extensive background in aeronautical research and development. He is an aeronautical engineer and former research pilot, and he will be very helpful to us in these areas in the future. Also, Dave Young comes to us from the Department of Defense, with an extensive background in the military aspects of aeronautics.

Mr. HECHLER. I would also like with unanimous consent to insert in the record a biographical statement. The world is familiar with your accomplishments and achievements but I would like the record to set them forth completely, and that will go into the record at this point.

(The biographical data on Hon. William A. Anders referred to above is as follows:)

WILLIAM A. ANDERS

EXECUTIVE SECRETARY, NATIONAL AERONAUTICS AND SPACE COUNCIL,

WASHINGTON, D.C. 20502

William A. Anders assumed his duties as Executive Secretary of the National Aeronautics and Space Council on September 2, 1969, after having been appointed to this position by President Nixon. He was born in Hong Kong where his father, Commander Arthur F. Anders, Retired, was serving in the Navy. The elder Anders received the Navy Cross for action as an officer on the gunboat Panay when it came under atack in the Yangtse River in 1937.

The former astronaut received a Bachelor of Science degree from the Naval Academy in 1955 and a Master of Science degree in Nuclear Engineering from the Air Force Institute of Technology at Wright-Patterson Air Force Base in 1962.

Mr. Anders was commissioned a second lieutenant in the Air Force upon graduation from the Naval Academy. After Air Force flight training, he served as a fighter pilot in all-weather interceptor squadrons of the Air Defense Command. After his graduate training, he served as a nuclear engineer and instructor pilot at the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, where he was responsible for technical management of radiation nuclear power reactor shielding and radiation effects programs.

The San Diego, California, native has logged more than 3,000 hours of flying time.

He was one of the third group of astronauts selected by the National Aeronautics and Space Administration in October 1963. He served as backup pilot for the Gemini 11 mission and was lunar module pilot for the historic Apollo 8 mission—man's maiden voyage to the moon—December 21–27.

Following the Apollo 8 mission, he served as backup command pilot for Apollo 11, the first manned lunar landing mission.

He is a co-recipient with Astronauts Frank Borman and James Lovell of the National Geographic Society's Samuel Hubbard Medal, the General Thomas D. White USAF Space Trophy and the Harmon Trophy.

He has also been awarded the NASA Distinguished Service Award, the space agency's highest honor; the Air Force Commendation Medal; Air Force Astronaut Wings, and the New York State Medal for Valor. He is a member of the American Nuclear Society, Tau Beta Pi, and Society of Experimental Test Pilots.

Mr. Anders is married to the former Valerie E. Hoard of Lemon Grove, California. They have five children, Alan, Glen, Gayle, Gregory and Eric.

THE NATIONAL AERONAUTICS AND SPACE COUNCIL

The National Aeronautics and Space Council is in the Executive Office of the President and was established by the National Aeronautics and Space Act of 1958.

It has the responsibility for advising and assisting the President with respect to policies and performance throughout the entire aeronautics and space field. This includes the space activies of the Department of Defense, the National Aeronautics and Space Administration, the Atomic Energy Commission, the State Department, etc. As outlined in the law, the Council's functions include the following:

(1) survey all significant aeronautical and space activities, including the policies, plans, programs, and accomplishments of all departments and agencies of the United States engaged in such activities;

(2) develop a comprehensive program of aeronautical and space activities to be conducted by departments and agencies of the United States;

(3) designate and fix resopnsibility for the direction of major areonautical and space activities;

(4) provide for effective cooperation among all departments and agencies of the United States engaged in aeronautical and space activities, and specify, in any case in which primary responsibility for any category of aeronautical and space activities has been assigned to any department or agency, which of those

activities may be carried on concurrently by other departments or agencies; and

(5) resolve differences arising among departments and agencies of the United States with respect to aeronautical and space activities under this Act, including differences as to whether a particular project is an aeronautical and space activity.

The members of the Council are the Vice President (Chairman), the Secretary of State, the Secretary of Defense, the Administrator of NASA, and the Chairman of the AEC.

Mr. HECHLER. I would also like to welcome the senior ranking minority member of the committee, Congressman Thomas Pelly of Washington to these hearings.

Mr. PELLY. Thank you, Mr. Chairman. I recall our hearings last year to which you referred in your opening statement. I think those hearings pointed up very definitely the fact if there had been the interest in research, say 10 or 15 years before, many of the problems we are experiencing today we would not be facing.

I am hopeful again this year we can have testimony from distinguished witnesses who will again help us to increase the emphasis that those of us who are on this subcommittee I know feel must be given to research and aeronautics. I, too, welcome the distinguished witness today.

Mr. HECHLER. Thank you, Mr. Pelly. Mr. Lukens, a distinguished member of the committee, do you care to make an opening observation also?

Mr. LUKENS. I want to say, Mr. Chairman, I welcome the opportunity. I do welcome the opportunity to say hello to the witness today.

Mr. ANDERS. Thank you.

Mr. MILLER. I want to say this off the record.

(Discussion off the record.)

Mr. HECHLER. Back on the record.

Mr. MILLER. I am very happy to welcome the Colonel here. He has undertaken a very important task.

Again we find our hands tied by traditions, and certain forms of bureaucracy. This committee technically can go no further than to talk about the technical side of aviation and what can be done in it. When it comes to some of the big things, or the operational phases, of course that is the responsibility of another committee. We have got to make very sure we do not encroach on their grounds, although it is a very fine line that divides us.

I am hopeful that perhaps some day the agencies having to do with the operation of airplanes, in the private sector, will have some coordinating agency in Government that can help them. The CAB and the FAA all are concerned with these matters. These matters are not our principal concern, yet we cannot overlook them.

As one who has to depend on transportation to get around the country and across the country, I realize the great boon the aviation industry is to us, except when an airport is socked in. One of our members, who is chairman of a subcommittee, was up in Hartford last week. He got up at 7 o'clock in the morning so he could get a plane to come here to conduct a hearing at 10 o'clock. About 11 o'clock we got a telephone call from him from Norfolk. The Washington Airport was "socked in."

In my own case I remember I was wanting to go to Boston one time. When we got to New York we were grounded. At 3 o'clock in the

morning they started us up on a series of buses that got there—we left at about 11 o'clock at night, I guess it was, Dick?

Mr. HINES. Yes, sir.

Mr. MILLER. We got into Boston at 3 o'clock in the morning. I was on a discussion panel at 10 o'clock. I think it would have been much better if I had stayed at home.

But I am saying this now for the benefit of my colleagues on other committees.

It is indeed hard to get into small towns in the Middle West now. My wife's people came from a very small town in Nebraska. Then we would have to get off the train in Denver and catch a local into Omaha. But, it would stop at a town within only 4 miles of my wife's home. Today if you want to get into the same community you take a bus two-thirds of the way across the country. If you go by air, you are not too certain whether or not you are going to get into the small airport of this town. It is very hard to figure on.

I think these are some of the things that have got to be taken care of. In aviation, a good deal of it is the technology that can furnish necessary equipment for bad weather landing. I am sure in the future we will break through the fog barrier and be able to land in all types of weather. That is one of the things that we must be concerned with. The pressure for this should be coming from other agencies of Government, too. I am a little afraid this hasn't been the case.

This isn't your problem, Colonel. It is the problem of the country, but it is the thing that you and this committee must look to because we do have some secondary responsibility in the field. Thank you, Mr. Chairman.

Mr. HECHLER. I appreciate your comments, Mr. Chairman, and commend you for the leadership you have exercised in the field of aeronautics. I would like to also make it perfectly clear for the record that it was at your suggestion that these hearings on aeronautical research were initiated.

Mr. Anders, once again we welcome you and you may continue with your statement.

Mr. ANDERS. Thank you.

It is a great pleasure for me to appear before your subcommittee today.

This is my first appearance before Congress as Executive Secretary of the National Aeronautics and Space Council. It is appropriate that this first appearance of mine deals with aeronautics since, as I have mentioned several times in conversation with you, Mr. Chairman, I intend to insure that the responsibilities in aeronautics that have been assigned to the Council and its staff are not neglected.

Mr. Chairman, I have been reading with great interest the documents reporting on previous congressional hearings and staff investigations concerned with aeronautics. These review activities have performed a great service to the Nation by identifying many of the problems which threaten to diminish the healthy growth of air commerce and the essential development of military aviation in our country.

Since I assumed the office of Executive Secretary of the National Aeronautics and Space Council just last September, I feel that it would be presumptuous for me to suggest that in the brief time I

have been on the job, I could become sufficiently expert in this complicated field to make a significant contribution to a detailed listing of the problems which face aeronautics today. Much of this identification has already been done well by experts in this field, not only in your past hearings, but through reports in the technical and professional journals; through articles in the trade press; and through the publication of technical studies by those Government agencies concerned with various aspects of aeronautics. But, though I still have much to learn in this area, it does seem to me that our national aeronautics problems can be placed into the broad categories of basic research and development, flight vehicles and propulsion, air traffic control, airport planning, and public irritants.

What I would like to concentrate on this morning are my plans for the organization of my staff and the role of the National Aeronautics and Space Council with respect to the national aeronautics effort and its relationship with the Government agencies and departments that are concerned with aeronautics. This will be without regard to whether these agencies are statutory members of the Council.

In order to fulfill the aeronautics responsibilities assigned the Council by the National Aeronautics and Space Act of 1958, I am reinforcing my staff with aeronautical specialists. As a stop-gap measure, to bridge an excessively restrictive budgetary situation, I have had these specialists detailed to the NASC staff from NASA and the DOD. Hopefully the situation will soon ease and I will be able to employ this type of expert help directly. These experts will have recent experience in aeronautical research and development, technical management, and operations, as well as an appreciation of how the Government agencies and departments work within themselves, with each other, and with civil aviation.

My plans are that they will concentrate their initial efforts on specific issues within the broad categories of problems that have been identified. The solution of these specific problems hopefully will lead to a more clearly defined national aviation policy which will help establish national aviation goals. In this way we should be equipped to determine how aviation can continually improve its service to society. Of special importance, we should be able to identify potential problem areas that can be addressed before they become critical. Of course, the level of effort I am discussing this morning is contingent upon approval of the budget I am requesting for fiscal year 1971.

One of the first issues I plan to address is that of aeronautical R. & D. policy. A congressional report recommended almost 2 years ago that the National Aeronautics and Space Council act as the focal point for the development of a more comprehensive and better coordinated aeronautical R. & D. policy. Since my appointment as Executive Secretary of the Council, many aerospace professionals have expressed their personal hopes to me and members of my staff that the Council could indeed be the mechanism for top-level national focus on aeronautics. I agree that the Council could be very effective in this role. Therefore, my aeronautics staff and I intend to work closely with appropriate departments and agencies toward this goal.

Aeronautics covers a wide spectrum of activity: research, development, testing, production, certification, regulation, and operations. The areas most critical from a long-range point of view appear to be research, development, and testing, for these activities provide the con-

fidence and capabilities needed by the manufacturer and operator in order to progress. It is to these areas that my staff and I plan to devote our major attention. In addition, we recognize that our responsibility in aeronautics extends far beyond the development of flight vehicles. Our national policy must include consideration of the complex man-machine relationships within the environment in which the vehicle operates. One cannot change a part of the system without some effect on the others. Nothing worthwhile comes free in our world today, and that includes progress in aviation. Many times progress creates problems, and the problems frequently manifest themselves in the form of public irritants—noise, pollution, travel delays, and so on. Our staff awareness and understanding must extend to these types of problems as we work with the Government departments and agencies and with industry in seeking prompt realistic solutions for the minimum tax dollar.

In this discussion of Council responsibilities and methods of operation, I may have left the impression that the Council with its staff can be a panacea for all aviation ills. The functions and responsibilities of the Council in aeronautics, as stated in the National Aeronautics and Space Act of 1958, are quite broad and will be beyond the capabilities of the Council and a competent supporting staff unless we have the full support and cooperation of the governmental departments and agencies that also have responsibilities and interests in this field. Just as NASA cannot unilaterally be expected to solve all problems in aeronautical research and development, the NASC cannot unilaterally resolve all the vexing policy issues in aeronautics. I do not view the Council staff as a small research and development group. Nor are we an inspector general who grades the work of others. I do believe, though, that one of our chief responsibilities is the identification of gaps in aeronautical research and development which, if unfilled, will have a detrimental effect on the healthy progress of aviation. My staff and I will work closely with responsible departments and agencies as well as industry and the universities, so that we can anticipate problems and coordinate research in a timely manner to avoid the necessity for crash programs and other reactive activity. What I would like to see in the future is effective planning and policy on a national basis. This does not necessarily mean that the implementation of these policies or plans will be inexpensive.

However, by avoiding symptomatic solutions, such as the aspirin you mentioned earlier, the taxpayers should realize more research and development for his tax dollar. To assist in our planning, my staff will draw upon the many studies and investigations sponsored by other Government agencies and departments, as well as by the industry and trade associations. This procedure will also assist in our identification of today's and tomorrow's aeronautics problems. In this regard, we have already initiated an effort to compile the recommendations of the studies and investigations conducted during the past decade as a first step toward understanding the situation confronting us. We want to see what past recommendations have been acted upon and what reasons exist for those that have not. After this has been accomplished, I should be in a better position to answer the questions on aeronautics problems posed by this subcommittee and also be in a better position to formulate recommendations to the Council for policy consideration by the Chief Executive.

The development of an effective national policy for aeronautics requires the active cooperation and participation of all concerned organizations. When the Council was established by the National Aeronautics and Space Act of 1958, the statutory membership was representative of the primary Cabinet-level interest in aeronautics. Today, this country has three great agencies concerned with aeronautical problems: NASA, DOD, and DOT. Although not a statutory Council member, the Department of Transportation, since its establishment, has been invited to participate in all Council meetings when aeronautics has been a subject of discussion. This practice will continue and, I hope, it underlines the importance with which the Vice President and I view the Council's relationship with the DOT and its aeronautical agencies: the FAA and the Coast Guard. Since many of the publicly recognized problem areas fall within DOT's purview, any dialog preceding recommendations for national policy cannot be conducted without that agency's involvement. I intend, as my staff is developed, to increase our existing interface with DOT and its agencies to insure their timely input to Council deliberation and staff activity.

Each of the Government organizations that are active in aeronautics has its own unique talents, qualifications, and responsibilities. There is some overlap in research, development, and testing capability among them, but this is not in itself bad. Sometimes, the technique of multiple research approaches to solving a problem is the most economical in the long run. On the other hand, I believe that where there is overlap, care should be exercised to see that undesirable duplication of effort and facilities is avoided since every unnecessary duplicative effort wastes valuable manpower, facilities, and funds that could be more effectively applied to other areas in need of attention. Since we do not have unlimited funds, skills, and facilities as far as our Nation's aeronautical R. & D. needs are concerned, we cannot afford to divert what resources we have on unprofitable duplicative effort. Such unproductive effort can be avoided only through close interagency coordination and cooperation. To this end, I believe the Council and its staff can be most helpful. We would hope to be the catalyst for this process to assure that coordination of programs is taking place, and to encourage cooperative or complementary Government programs where the Nation would benefit.

The delineation of the activities and responsibilities of the three technically powerful Government agencies which have talents in aeronautics was easier in the past than it is today, but some generalization is possible. NASA, as the NACA before it, is the primary aeronautics R. & D. Agency of this Nation. The DOD has special qualifications in certain research areas, but of course its main capability and purpose lie in the development and operation of military systems. The DOT and its Federal Aviation Administration are charged by statute with research and development for civil air systems as well as insuring the safety of civil operations and the control of the Nation's air traffic.

The NASA statement made before this subcommittee last year did an outstanding job of describing the complexity of aeronautics and recognized how difficult it is to alleviate one problem without creating others. An aerodynamic research project may result in a new wing design of greater flight efficiency, but it may also influence the operation of the aircraft in the terminal area, causing the air traffic control

system to become overloaded. On the other hand, a new avionics breakthrough might make the acceleration of air traffic handling possible at one point in the ATC system while producing traffic saturation at another point. Limitations on operations at key airports due to noise restrictions or inadequate air traffic control capability can change airline procurement policies regarding new aircraft. Military technology applicable to the improvement of civil systems may be unavailable to the civil air system because of security reasons. These are illustrations of the complicated interagency problems which occur daily. I strongly feel that the Council and its staff can and must provide a useful and productive service in the key role of assuring that coordination and communication take place between Government agencies with aeronautical responsibilities.

I have not yet commented on one specific recommendation suggested for the Council in the past by a Congressional Report on Aeronautical Research and Development. In calling for an in-depth study on civil aviation R. & D. policy to be performed jointly by NASA and DOT, the Senate Committee on Aeronautical and Space Sciences recommended that as soon as the results of the study are available, the National Aeronautics and Space Council, with the Department of Transportation and Bureau of the Budget as participants, consider the appropriate level of Federal Government involvement in aeronautical R. & D. This joint NASA/DOT study has begun, and will, hopefully, provide some of the important answers we are all seeking. I am pleased to report that my staff and I have been in contact with the executive director for this effort. We are following closely the development of this study.

In summary, Mr. Chairman, I wish to assure you and the members of this subcommittee that I am attempting to implement the Vice President's wish that the National Aeronautics and Space Council be active in space and aeronautics. Aeronautics will receive Council staff attention. However, our success in dealing with aeronautics problems at a national policy level will be determined to a great extent by the interest and support provided by both the Government and private business. The task ahead for all of us is not an easy one, but I can assure you that the Council and its staff will work to assist in the development of a national aeronautics posture that is vigorous, effective, and responsive to the needs of our society. I wish to be as helpful as possible to this subcommittee. I believe my planned staff will be of assistance to you and your colleagues.

That concludes my statement, Mr. Chairman. I thank you and the members of the subcommittee for inviting me to appear.

Mr. Hechler. Thank you for this excellent leadoff statement, Mr. Anders.

As one of the three-man crew that first circled the moon, you may be in a position to answer a question I am frequently asked. How were you able to get up to the moon so successfully when now we are unable to solve a lot of these aeronautical problems of a more mundane nature? How do you answer that question?

Mr. Anders. I get that question with respect to a lot of the problems that face our country today, Mr. Hechler. It seems to me we could say that the job of landing on the moon really is kind of a simple one. The President stated his requirement. He gave the job to the engineers.

They brought out their slide rules to determine what was necessary, turned their computers on, and the Apollo system came out the other end. That, sort of oversimplifies it, but I think that puts it in some perspective.

Congress got behind them and provided the funds to do the job. This is mainly a technical job. The problem we are talking about today, aeronautics, is a technical one, but it is also a "people" problem. It reminds me of Dr. von Braun's comment when asked that same question. He said it reminded him of a situation at a large dinner party, where he knew where he was, he knew where his seat was, but it was always so difficult to get there because there were so many people in the way. These people problems are some of the hardest we have to address; we can't work them out on a slide rule—noise abatement——

Mr. MILLER. Would you also include in that "people's problem" sometimes there are political problems and, interpolitical problems too? I was in a dinner party in Los Angeles given by one of the people high in the space agency, and one of the guests was the mayor of Los Angeles. The president of the university interjected a question: "Mr. Miller, you talk about going to the moon. What are you doing in Congress about solving the transportation problem in Los Angeles, getting people to and from these places?"

I said, "Doctor, we are not doing anything in Congress about that, because if we did, the gentleman sitting next to you, who happens to be the mayor"—now the mayor and I started in politics together in 1936, and I served with him in the House—I said, "the gentleman *sitting next to you* would be up on his hind legs just screaming to high heaven."

George, you will pardon me because this comes from your part of the country—this was Government interference with the municipalities of the people of the State, and the duties of the State officials and the Federal Government. Isn't this part of your problem, too?

Mr. ANDERS. That is included in what I meant by "people" problem.

Mr. HECHLER. I would like to make one further observation before throwing the discussion open to other members of the committee.

I never cease to underline the fact that the organization of which you are Executive Secretary is called the National Aeronautics and Space Council. You are operating under the authority of the National Aeroanutics and Space Act of 1958. This committee deals in its major relationships with the National Aeronautics and Space Administration, and it is for this reason that we are putting so much emphasis on aeronautics.

You referred to the National Aeronautics and Space Act of 1958, and I would just like to include for the record at this point those portions of the National Aeronautics and Space Act of 1958, as amended, which define the functions of the Council of which you are Executive Secretary:

> To advise and assist the President in the following: (1) Survey all significant aeronautical and space activities including policy plans, programs, and accomplishments of all departments and agencies of the United States engaged in such activities; (2) develop a comprehensive program of aeronautical and space activities to be conducted by departments and agencies of the United States; (3) designate and fix responsibilities for the direction of major aeronautical and space activity. . . .

So you have a very broad charter for aeronautics in the National Aeronautics and Space Act.

I am very pleased that in your opening statement you recognize the scope of responsibility, and the capacity and potential for future leadership in the development of future research which the National Aeronautics and Space Council has.

Mr. Brown, do you have any questions or observations?

Mr. BROWN. I don't have any questions right now, Mr. Chairman.

Mr. HECHLER. I am pleased to welcome Mr. Fulton.

Mr. FULTON. I am glad to be here.

Mr. HECHLER. Do you have any questions or statements?

Mr. FULTON. I think Mr. Lukens and I were talking about the problem of not only the people but of the traffic congestion, the mere congestion of people. On the moon you don't have this congestion, as yet.

I have been interested in the Space Council, and have questioned whether the membership was set too high when it was set at Cabinet level.

I feel that people who work on a more practical basis should be put on the Space Council—Dr. Pickering might be one, or the head of Manned Space Flight might be another, or somebody from the operating agencies, or the overseeing agencies of the aeronautics industry. Would it be possible to bring it down out of the clouds and get a much more close interface with Council members that are more in the operation? For example, Dr. Werner von Braun might be a good suggestion, or General Phillips and George—Dr. George Mueller.

Mr. MILLER. Will the gentleman yield?

Mr. FULTON. Yes.

Mr. MILLER. I perhaps have a little more experience in this field than most of you because I was chairman of the first Subcommittee on Oceanography established in the Congress—you were on it Mr. Pelly.

Mr. PELLY. I was on the committee.

Mr. FULTON. We on this committee have always regretted that you got it away from us.

Mr. MILLER. Well, we had another interagency committee on oceanography which was pretty much on the level of which you speak. It never got anything done because the people who came there wouldn't speak for their agency. They had to go back and get the permission of the head of the agency.

So I think when the Space Council was set up, that they did put the heads of departments on it. But the heads of departments can designate people to act for them and be present for the agency, but at least they have the direct line with the secretary. I think this is something you would want to watch and study very carefully before any changes were made in the Act with respect to the membership of the Council.

Mr. FULTON. I think probably the Secretary of the State Department is unnecessary on the Space Council.

Mr. HECHLER. Will the gentleman yield?

Mr. FULTON. I will be glad to.

Mr. HECHLER. Excuse me, Mr. Chairman.

Mr. MILLER. He mentioned the Secretary of State. You don't know, whether or not in the not too distant future, the Secretary of State's position on the Council may be very important. Right now NASA has entered into an agreement with India to orbit a communications satellite, to beam right into 2,000 schools in India for the purpose of establishing education in these places.

This is the place where you are going to need someone from State, and someone high enough up in State who can talk to the Secretary if problems arise in this field. This is merely one of them.

Mr. FULTON. The point of my request was I would like to see how many of these top-flight people ever came to any of the meetings, or knew anything about it.

Mr. MILLER. How often do you send your administrative assistant to Congress?

Mr. FULTON. Maybe we should ask the witness.

Mr. ANDERS. We have had two Council meetings since I have come onboard. In both cases we have either had the principal designated by law, or one of his immediate decisionmaking level people present.

With respect to what Mr. Fulton has said, I view the National Aeronautics and Space Council and its staff to have a twofold value. I think, frankly, one of the most significant values it can have is through the activities of its staff, whose interfaces are with the kinds of people you mentioned; and as a matter of fact, I think every one you mentioned we have had contact with in just this short period I have been onboard—Werner von Braun, Dr. Pickering—because these are the operations people; these are the doers, and these are in fact the staff members of the principal's staff.

We feel it is very important for our group, the Council staff, to have a very close interface with the various agencies at the working levels, to be able to generate appropriate staff work, to be able to look ahead into the future and talk to these people and get their advice, in order that we can present to the principals themselves essentially a completed effort. By the time the Vice President, Mr. Laird, or his designee, Dr. Seamans, Under Secretary Johnson, Dr. Paine, and Dr. Seaborg get together as our Council, we want the package pretty well in hand so they can have some final discussion on it and either approve or disapprove the plan.

I think in effect, Congressman, we are implementing your desire, and it certainly is our desire to do just that, because we feel that we, the Council staff, cannot operate in a vacuum. We cannot sit over in the Executive Office Building and pontificate space and aeronautic policies. We have to go out and find out for the President what it is his great operating agencies feel are required in the future. Check with the universities, scientific communities, check with the public and private enterprise, check with Congress, and all the other forces that are bearing on any decision that he might want to make on space or aeronautics.

Mr. FULTON. I am glad the Vice President is so interested in aeronautics and space, but I can hardly believe he has been at a meeting, in all good humor, because when he is associating with you intellectuals there have been no quotes. Let me ask you to supply for the record: The relationship to the activities of the National Aeronautics and

Space Council of Col. Frank Borman, U.S. Air Force (in his present capacity), and Col. Michael Collins, U.S. Air Force, in his future role as Assistant Secretary of State for Public Affairs.

Mr. ANDERS. Yes sir.

My statement is as follows: Colonel Frank Borman, USAF, is presently assigned to the National Aeronautics and Space Administration in the capacity of Field Director, Space Station Task Group; I flew with Colonel Borman on Apollo 8; he is a man with considerable experience in the aerospace field and one whose judgment is greatly respected at all levels of government and industry. Colonel Borman has no direct relationship with the National Aeronautics and Space Council that would differ from that of any other senior NASA official. Colonel Borman has, from time to time, been assigned specific space-related tasks by the President; e.g., foreign goodwill trip, Apollo 11 crew dinner and ceremonies, Cosmonaut visit.

Colonel Michael Collins, USAF, will soon be assuming his new position as Assistant Secretary of State for Public Affairs. As you know, the Secretary of State is, by law, a member of the National Aeronautics and Space Council. While Colonel Collins' new position is strictly in the field of Public Affairs as it applies to State, there can be no question that his advice on space matters would be available to the Secretary of State as desired.

Mr. FULTON. When he has been associating with you intellectuals, maybe you—plural—intellectuals, there have been no quotes from the Vice President.

Mr. ANDERS. He made a comment in one of his speeches, talking about the problems afflicting our country, addressing himself to the sort of question Mr. Hechler asked, about how can we go to the moon and not solve—I think he made some comment that said what we need to do is transfer some of the spirit of the space program to other programs. I know he is interested in space and in aeronautics.

Mr. HECHLER. Getting back to the question of the membership of the Council which was raised by Mr. Fulton, I noticed on page 4 of your prepared statement that you comment on the fact that the Department of Transportation, although not a statutory member of the Council, has been invited to participate in all Council meetings when aeronautics has been the subject of discussion.

It would seem to me because of the great importance and the central role of the Department of Transportation, that Congress should make the Department of Transportation a statutory member of the Council. I simply make that as an observation rather than an assertion, and I would be pleased to get your reaction.

Mr. FULTON. I agree with that, too.

Mr. ANDERS. Quite possible, Mr. Hechler, I am not yet at the stage of my learning process in Washington where I can form an opinion—I am not yet familiar with the problems and advantages involved.

Mr. MILLER. Could I make a suggestion to the subcommittee chairman?

Mr. HECHLER. Yes.

Mr. MILLER. If in the report of this committee to the full committee, you should suggest this, I am certain that the full committee would also suggest it, and it would be a very simple matter to render a bill to accomplish this. The Department of Transportation should be in here. It came into being later, so here is one item you might put into your report if you saw fit. I am not going to ask you to do it—George is shaking his head.

Off the record.

(Discussion off the record.)

Mr. MILLER. Back on the record.

Mr. HECHLER. Mr. Fulton.

Mr. FULTON. May I have one point? May I make one comment on the statutory language? Is the language applicable at the present time when it more or less says to the National Aeronautics and Space Council that you are to actually come up with the programs—sort of a super departmental programing agency between the departments and the President?

Is that language accurate at this time, according to what you say in your statement?

Mr. ANDERS. Mr. Congressman, I am not a lawyer and hesitate to try to interpret exactly what this wording implies. It could imply that or it could imply something else.

I think that the limitations of the Council staff would preclude doing NASA and DOD and the principal's planning jobs for them.

I think, we, as the staff, advising and supporting Council members, have to insure, are obligated to insure, that such planning activities are in progress in the various agencies which are members, and also in the nonmember agencies with respect to those who are interested in space and aeronautics. We must try to be helpful in pointing out where possible gaps in plans and policies exist.

I view our job in reading the letter of the law, then trying to assimilate it to try to determine what I am supposed to do—I view my job as looking at space and aeronautics through the President's eyes, to try to see what view he would take of the various problems and plans and policies, and therefore try to be in a better position to have my staff develop the policy problems and planning areas you are suggesting for action.

Mr. FULTON. Then how would you fit in with the President's science adviser in his staff?

Mr. ANDERS. I think the President's science adviser, Dr. DuBridge of the Office of Science and Technology, has a similar responsibility. He looks at science—this is a 3-month experience I am speaking from now—it is my understanding he looks across the broad spectrum of science and technology, and advises the President how the Nation should best proceed for proper development of these areas.

In one aspect of science and technology would fall space and aeronautics.

We look at it the other way, the other dimension, looking at space and aeronautics in a national way to include those aspects of it that would fall into the category of science and technology. But I submit that there is more to space than science and technology. It must be looked at in its total context—national security, international cooperation, national spirit, and those kinds of things.

I would say Dr. DuBridge and I would form part of the administration team in developing for the President the best space and aeronautics policies and best science and technology for the Nation. We are meeting this afternoon to discuss future space and aeronautics plans.

Mr. FULTON. I had recommended there be a second astronaut. As a matter of fact, I had a bill in to include an astronaut, a practical working astronaut, as the Executive Secretary is usually called, and one additional member on the Council. Would you recommend that?

Mr. MILLER. Mr. Chairman, Mr. Fulton, I think it is rather embarrassing to ask this question of the gentleman. After all he is not a Member of Congress, and he represents the administration. Before he could answer that he would have to clear it with the White House.

Mr. FULTON. Thank you. That is all.

Mr. HECHLER. May I comment on some of the very significant statements you have made in your prepared testimony concerning the need for a national aviation policy?

Starting on page 2, in the middle of the page, you state:

The solution of these specific problems hopefully will lead to a more clearly defined national aviation policy which will help establish national aviation goals.

And then again at the bottom of page 3 and top of page 4, you say:

What I would like to see in the future is effective planning and policy on a national basis.

And the beginning of the paragraph in the middle of page 4:

The development of an effective national policy for aeronautics requires the active cooperation and participation of all concerned organizations.

I would like to focus the searchlight on those statements because I think those statements are highly significant and underline the need for the enunciation of a national policy.

The more that we get into this subject, piecemeal, in Congress, the more we begin to understand the necessity for looking at this picture in broader perspective. And if we are to apply the lessons of the successful trip to the moon to the problems here on earth, as you suggested, we can use that example by focusing attention on the development of a national policy for aeronautics, which clearly, of course, is the function of the Chief Executive, as you so well put forth here. But I would just like to commend you for bringing this whole problem into focus, and see if you have any other observation to make on the need for a national aviation policy.

Mr. ANDERS. My feelings at this time are very preliminary, Mr. Chairman. But it occurs to me as a military pilot, test pilot, private pilot, what-have-you, that you just can't look at any one section of the pie and try to define the whole pie.

Just as this subcommittee must sometimes at least be aware of activities falling under the purview of other subcommittees it is my view you can't address yourself to the aviation problem today without going all the way from aerodynamic basic research to baggage-handling at New York Airport. I think each has its effect upon the other. This is a pretty big problem, and I think it will take a lot of work by a lot of people. But it is one that we hope to at least look at and try to give attention to in order to develop guidance to help and assist the President as he may request in these areas.

Mr. HECHLER. I hope one of the things, Mr. Chairman, that will come out of these hearings and in the report this subcommittee writes will be the development of a national aviation policy and the recommendations that such a policy be enunciated.

Mr. Pelly.

Mr. PELLY. Thank you, Mr. Chairman.

Colonel, first of all, I would like to say I think for your first experience of being before a congressional committee you have done mighty well. More probably for the reason that you forthrightly

indicated your lack of being on the job very long, and you didn't stick your neck out at any point that I could see. I think you probably didn't emphasize in your statement something that maybe you realize, and that is, there is a tremendous amount of public interest now in your particular responsibility.

The University of Washington is in my district, and recently I read students there were actually more interested in environment than they were in the Vietnam War, if they could be more concerned about anything.

But it seems to me with your noise abatement that you mentioned and pollution and the other problems of air, you have certainly touched a spot that indicates the importance of your assignment and significance of your assignment.

Before you started your testimony I referred back to the previous hearing. It was indicated that, if 10 or 15 years before we had done the research, we wouldn't have many of the problems we have today. I was thinking, when you were talking about flight control, and other matters, that in the previous testimony before our subcommittee I think the statement was made, wasn't it, Mr. Hechler, there isn't an airport in the country today that you can take two 747's at the same time. Or maybe it is more than two 747's because of the baggage congestion. I remember being told more people meet an airplane actually than get off of it.

So now today the 747 has come into being. The first one is in process of being delivered to Pan American now. I wonder how many airports today are prepared to take care of the 747. There are 10 of them sitting out there on the field in Renton, Wash., waiting to get their engines, and then they are going to be delivered. We are way behind in our research work on the various airports in the country.

This is where I hope you are going to be reporting to the President and giving greater emphasis to research. The 747 as a result of research is not as noisy as the 707. It goes right over my house out near Seattle practically every day. It isn't noisy as far as I can tell at all. I don't believe there will be any problem with noise.

The House has made a momentous decision that we are going ahead with the SST. There again that is going to fly over water. You have to be thinking in terms of research to take care of it in the 1980's; it is the plane of the 1980's.

I want to say I think your appearance here has been to me very encouraging and tremendously significant because of the fact of your background and experience. With your experience you can meet many of the research needs now and not have them delayed for 10 or 15 years more getting people to and from airports, and all the problems that you are going to be conversant with in the ears and eyes of the President. I welcome you here today. I look forward to your future appearances.

Mr. ANDERS. Thank you.

Mr. HECHLER. Thank you, Mr. Pelly.

Mr. BROWN. Could I ask a question?

Mr. HECHLER. Mr. Brown.

Mr. BROWN. Mr. Anders, in this area of coordinating research, and identifying the gaps and so forth, it seems to me you have a problem in certain areas as a result of classification situations, and I want to ask this particular question.

With regard to safety in aircraft, we badly need some research and development that will identify possible collisions and possible crashes and that sort of thing. We seem to have some marvelous developments in radar and radar control of aircraft, such as in the F-111, and things like the descent radar on the landing craft on the moon.

Is there likely to be a problem as far as your coordination of research, in that certain types of data which might be available are classified, and there is an inadequate ability to get the application of this to civilian uses, such as aircraft safety?

Mr. ANDERS. In the development of my staff, Congressman, I have military people detailed to me at this time, people who have backgrounds in the areas that you are talking about, in the areas that are in some cases classified, and many cases not classified. I hope to get more experts, because though we can sit here today and discuss our interest in aviation, it still takes people to be able to do a decent job.

It would be my hope that the military cognizant people would be able to transfer to those looking at the civilian side of the house, expertise and information on R. & D. available that may be classified and not generally available, and to assist in either the declassification of this information, to make it available to the general public, or to bring those members of the general public, the industry teams, into the classification levels that are required to make them aware of this area.

In regard to your comment on safety and collision avoidance: Certainly the lunar program has been very instrumental in developing miniaturized and highly reliable electronics components and organizations like the NASA Electronics Research Center in Boston, could be and have been helpful in spin-off into avionics for aircraft and general aviation field.

We hope to be able to be a catalyst in assuring that this kind of thing not only continues but accelerates.

Mr. BROWN. Well, I mentioned these specific examples merely indicating apparently we have developed highly sophisticated devices for guiding vehicles based upon proximity, the F-111, and the lunar landing craft are both examples of this sort of thing.

It would seem to me to be a disaster, if for reasons of classification, technological know-how is not translated into solving the problem of aircraft above airports, for example. Or in the case of aircraft, we have had two incidents in apparently a very short period of time, where they collided with some mountains close to an airport.

I would like to be assured, and I recognize you are not in a position at this point to give me any assurances, but I would like to feel personally assured, and I think the Congress would, that the knowledge that we have in one pocket is not going to be kept secret for the solution of problems that may occur in another area.

I would hope there is a mechanism through which you can handle this, through the Council, more adequately.

Mr. ANDERS. Yes, I would say that is definitely one of the responsibilities of the Council and the staff.

I would venture to say, even though I haven't been onboard very long, that the main problem facing us in the solution of aeronautical or aviation questions of this Nation is not one of classification, but one of economics.

Mr. BROWN. In other words, we could have a very good system for guiding the F-111, but it would be too expensive to guide a civilian aircraft, is that the theory?

Mr. ANDERS. Yes. Certain satellite systems are under study at this time by NASA and other agencies, which could enhance the accuracy of traffic control. But I am not convinced at this moment that is the real problem. It may well be a procedural problem of traffic control. I don't think you can look at any one thing as being a panacea to the ills that face us. Quite possibly we are going to have to stop taking aspirin, or more pills, and look at this from a new antibiotic point of view.

Mr. BROWN. Just personally I would hate to think we had reached the point where we could develop something that was not too expensive for military use but was too expensive for civilian use, something in that situation bothers me a good deal.

With regard to coordination of policy as between military and civilian space programs, have you had an opportunity to get involved in this to any degree—the fact the DOD has roughly a $2 billion a year military space program as compared with the NASA program? Is there a need to more adequately coordinate these two types of programs?

Presumably, this committee would have some cognizance of that problem, but as a member of the committee I confess to having had a great deal of difficulty in finding out information about the military space program. I would hope that there is some agency which would carry on some role of coordination as between these two.

Mr. ANDERS. Mr. Brown, as you know, the President's Space Task Group met last winter, spring, and summe , and addressed itself to what our Nation's future should be in space, and has recommended several options to the President which he is studying at this time. This report was submitted before I took office but I am somewhat familiar with it. I can assure you great consideration was given to both the Department of Defense and the NASA space programs to attempt as far as possible to make them complementary, rather than competitive programs.

I don't think that more adequate, as you put it, coordination is required. I think we must have a continuing coordination between these two great agencies. There are organizations to do that. There is a group called the AACB, which stands for Aeronautics and Astronautics Coordinating Board, established by the Department of Defense and NASA which meets on about a monthly basis to address itself to these kinds of problems.

We in the Council, and staff, have the responsibility to assure this coordination between agencies. You can be sure that I and my staff will maintain a visibility across the board in the various military and civilian space programs, and in aeronautics programs, to try to assist in this difficult job of coordination.

Mr. BROWN. I would like to explore this further with you next year possibly and see how much opportunity you had to get a feel for the success or the ongoing correlative of this coordination as far as your own agency is concerned. I have a feeling for a number of reasons there may be a little difficulty in providing the coordinating func-

tion at the congressional level. I would like to be reassured somewhere it is going on.

Mr. HECHLER. You mentioned the Space Task Group. I don't think it is revealing any State secrets to indicate several members of the committee had an opportunity to present our suggestions to the Vice President prior to the convening of the Space Task Group. This was before they began their analysis or began to prepare any report.

At this meeting I stressed very strongly my own personal feeling that the area of aeronautics should be treated by the Space Task Group as part of its function. The Vice President expressed his interest at the time.

I was quite frankly disappointed that the Space Task Group in its report did not direct its attention to the area of aeronautics and its relation to space.

I wouldn't want to ask you to comment on that omission, but I would like to ask you this question: Wouldn't it be advisable to have an aeronautics task group that could do the same job for aeronautics that the Space Task Group does for space?

Mr. ANDERS. Quite possibly, Congressman. At least it needs attention, in my view. At the risk of disappointing Mr. Pelly, and sticking my neck out, I would like to say that the Space Task Group had the narrow charter of looking—by "narrow" I use that in quotes—of looking at our country's future space program.

It convened experts in the area of space. Possibly their charter should have been expanded to include the area of aeronautics, but had it been, another group of people, I think, would have also been required.

It is quite possible by making the job so big to include both space and aeronautics that they would not have gotten the original part of the job, the space job, done.

Hopefully in the future the information from that kind of an activity will be developed—an aeronautics task group type activity such as you mentioned.

Mr. PELLY. Mr. Chairman, will you yield?

Mr. HECHLER. Yes.

Mr. PELLY. Wasn't it at that time we had to set it in the direction that we were going as far as space exploration is concerned?

Mr. ANDERS. Yes.

Mr. PELLY. Therefore, there was an urgency that probably dominated that particular report?

Mr. ANDERS. Yes.

Mr. PELLY. But I agree with Mr. Hechler we must get more emphasis, and hopefully it will come from the Aeronautics and Space Council.

Mr. ANDERS. Yes. I am agreeing with you on that point, sir.

Mr. HECHLER. I would just like to make this observation. I think it is unfortunate, however, that the problem is getting bifurcated. It is all very well to have an aeronautics task group or have the Aeronautics and Space Council do something on this subject. I feel though it is unfortunate when we have a National Aeronatuics and Space Administration, National Aeronautics and Space Council, all working under the authority of the National Space Act, why we have to divide the two because there is a relationship. Aeronautics should be given equal status instead of pushing it aside and brushing it under the rug.

Something that has not been mentioned today although you alluded to it in your remark about the tremendous public interest. I think the space program will get additional public support by emphasis on these areas like aeronautics, where we can see the results, and where they have definite contribution, not only to the civilian economy, but to solving the mundane problems that we are confronted with.

Mr. PELLY. If I might ask you to yield a little further. I think maybe those of us who feel as you have stated probably should actively elicit more emphasis, and possibly have another meeting with the Vice President on that very subject.

I would certainly join with you in that effort.

Mr. HECHLER. I appreciate that.

I would like to ask one further question now on the statement you made on page 6, the top full paragraph on page 6, where you make reference to the joint NASA-DOT studies, and the last sentence of that paragraph you say, "We are following closely the development of this study"—merely to give us an indication of just what the role is in a study like this, I wonder if you would elaborate a little bit on what you specifically mean by following closely the development of this study, and what is the precise relationship of the Council to this study. What kind of leadership do you give to it, and can you give to this type of study?

Mr. ANDERS. With your permission, sir, could I ask Mr. Enders to answer that question? He has been involved directly in this area.

Mr. HECHLER. Yes. Mr. Enders.

Mr. ENDERS. Thank you, Mr. Chairman. You asked for a precise definition of the role which the Council and the staff would play here.

I think it is quite difficult to define the role at this time with precision, except to refer to the charge given in the Senate committee's recommendation. Both the effort itself and our relationship with it are still in the developmental stage.

By following the development of the study effort very closely, as we are doing right now, we can hopefully help to reduce the time which it would otherwise take for the recommendations resulting from this study to be given consideration, thus accelerating the realization of potential benefits to the research and development planning process.

I think our staff can perform a service by identifying those particular developing ideas, as the study goes along, which might be suitable for implementation by the appropriate agencies.

This is the relationship that the Council staff sees right now to the joint study effort.

Mr. ANDERS. I would like to add, Mr. Enders has been invited to be an observer at the deliberations of this group, and has been meeting with Mr. Greene and his associates since he has been with the Council staff.

Mr. HECHLER. If you do observe a vacuum in a particular area they are addressing themselves to, is this the kind of action the Council could appropriatedy take to make sure that vacuum is filled?

Mr. ANDERS. Yes. It is my view Mr. Greene and his group are extremely well qualified to address themselves to the charter that has been given them; the involvement of the Government in aeronautical R. &.D.

This is a large piece of this pie I was referring to, and as we become smarter and look at the total aeronautics picture, we, as a staff, would expect, if we find vacuums or other pieces of the pie that aren't being addressed, we should try to stimulate activity in those areas.

So, when all is said and done, we don't have a bunch of pieces of a pie or puzzle that all overlap, but actually fit together. Quite possibly we could then be in position to assist with the determination of a national aeronautics policy.

Mr. HECHLER. Mr. Pelly or Mr. Brown, do you have any further questions?

Mr. PELLY. No further questions.

Mr. HECHLER. Any questions, Mr. Boone?

Mr. BOONE. No questions, Mr. Chairman.

Mr. HECHLER. If there are no further questions, gentlemen, thank you, Mr. Anders, and your associates for coming before the committee.

This has been extremely helpful testimony which will assist in the focusing attention on the need for additional activity in aeronautics.

We want to encourage you in your job and indicate the committee stands behind you and hope you will call on the committee for any assistance you may need in the future. We hope we may help you in your efforts to place additional emphasis in this most important area.

Mr. ANDERS. Thank you, sir. I look forward to working with you and your colleagues.

Mr. HECHLER If there are no further comments, the committee stands adjourned until 10 a.m. tomorrow.

(Whereupon, at 11:17 a.m.. the Committee adjourned, to reconvene at 10 a.m., on Tuesday, December 2, 1969.)

AERONAUTICAL RESEARCH

TUESDAY, DECEMBER 2, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10:04 a.m., in room 2325, Rayburn House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. We are pleased to welcome for the second day of these hearings on aeronautical research, the Honorable James M. Beggs, Under Secretary, Department of Transportation.

Secretary Beggs is one of the many alumni of the National Aeronautics and Space Administration, and he has testified before the committee on other subjects in the past, and we certainly welcome you, Mr. Secretary, this morning.

STATEMENT OF JAMES M. BEGGS, UNDER SECRETARY, DEPARTMENT OF TRANSPORTATION

Secretary BEGGS. Thank you, Mr. Chairman.

It is my pleasure to be with you again this morning and to be able to discuss this important area of aeronautics, in which, of course, the Department of Transportation has a vital and continuing interest.

First, I would like to discuss the question of the appropriate role of the Federal R. & D. programs in the field of aeronautics and the problem of leadership in this R. & D. which have been raised so often in the past. I think I have some appreciation for this matter, having served with NASA, as you gentlemen know, prior to assuming the duties of my present position.

Our principal effort in this area centers around the formulation of a DOT/NASA joint study of civil aviation R. & D. policy. DOT has the responsibility for coordinating this effort. In addition to DOT and NASA personnel, we expect to have representation in the conduct of the study by DOD and the aviation industry.

This is a substantive expansion of the study we discussed with you in September of 1968. The study effort has been greatly expanded in keeping with the scope of the question it addresses. Dr. Paine and I have confirmed our respective agency participation and our personnel have outlined a preliminary study plan, initiated a contract study of historic benefits derived from Federal R. & D., and have had our first advisory committee and working group sessions.

We anticipate that the conduct of the joint study should prove of great value in establishing much more precisely than in the past what

the government level of effort should be in aeronautical R. & D. and where the emphasis should be placed.

In this study effort, as in the past, we continue to enjoy a good working relationship with NASA. As you know, we have had for some time formal agreements with NASA regarding the coordination of R. & D. programs and technical support for our programs such as the SST and tracked air cushion vehicle development. Coordination on an informal basis between representatives of the two agencies has always been prevalent, and has been the real strength behind the formal agreements.

We are partciularly pleased that this year for the first time a working arrangement has been achieved between DOT and NASA for reviewing each other's preliminary budgets as they pertain to aeronautical R. & D. A primary objective of this action has been to assure that, prior to codification in the President's budget, programs in civil aviation R. & D. are complementary, and that these programs are responsive to needs we jointly identify.

I believe there has always been an appreciation on the part of DOT and FAA for the special capabilities of NASA, and we look forward to continued cooperation with NASA in our future relationships. We are conscious more than ever of the need to preserve those resources on which we have drawn over the years in our safety and regulatory efforts. We feel it is incumbent upon both agencies, however, to insure efficiency in the management of aeronautical R. & D. in the Government, and I believe in the continuing dialog between the two agencies, hearings such as this one, and joint efforts such as the policy study will prove to be important steps in achieving that goal.

In addition, I believe that the exchange of personnel both in the headquarters offices and the research centers of the two agencies would promote the productivity of the aeronautical research of both agencies. We have initiated discussions along these lines, for example, regarding possible DOT utilization of the Langley noise facility, if NASA determines that it will be included in the program.

We, as a nation, and DOT in particular, have a number of pressing problems facing us in aviation and I want to discuss them in the context of the overall Federal R. & D. effort. DOT is charged with the responsibility for operating the airway system, administering the Federal-aid airport program, and issuing regulations for the abatement of aircraft noise.

We are progressing toward solutions in these areas, but we need the help of Congress and of NASA to meet the demands of the problems. We must apply our resources judiciously toward immediate solutions and toward efforts which will maintain a constant flow of new technology into the aeronautical arena to meet future problems.

NASA is particularly well equipped to engage in advanced research in all aeronautical areas and has demonstrated its acumen in several areas of technological application. We rely on them to carry out the invaluable functions of exploring the "possible" in the various disciplines such as aerodynamics, electronics, propulsion technology, and human factors, so that there can follow a development by NASA, DOD, FAA or industry of the "applicable."

Much of this exploratory research should be conducted relatively free of constraints. However we see the role of DOT in this area as

that of establishing objectives and providing guidance which will insure that the research effort is applied in areas where it is needed most. Obviously, a close relationship must be maintained between DOT and NASA in this endeavor.

The partition of efforts between DOT and NASA is not clear at this time, and I do not believe we should attempt to draw hard and fast lines across which the two agencies should not venture. In noise research, for example, we have an almost complete interlacing of efforts from basic research through technology demonstrations leading to FAA regulations on noise certification.

In the development of new aircraft technology for increased speed, efficiency, and the like, NASA is the primary source of expertise not only for DOT but for DOD as well. The support given by NASA to our SST project is but one example of many areas where NASA has made an invaluable contribution.

There are numerous other areas where we are relying on continued or expanded effort by NASA. Some examples are: STOL aircraft high-lift devices, new methods of obtaining controllability, better displays in the cockpit, and direct-life control. Research in such areas as these would contribute a greater measure of safety, dependability, and economy to civil aviation.

Continued and expanded noise research is also needed to support the exercise by FAA of its regulatory authority in this area. Also, general aviation aircraft can benefit from more resilient corrosion resistant materials, and new fabrication processes and new lightweight materials can help reduce the high costs in the operation and maintenance of aircraft.

In the area of air traffic control we look to our own resources for system development and implementation with NASA playing a lesser role insofar as near-term hardware is concerned, but a key role insofar as longer term efforts on advanced systems components are concerned.

It seems fair to say that many of the current aeronautical problems we have stem from the phenomenal growth of aviation. This growth has been very substantial for several years, and it promises to continue in like fashion for many years to come.

Heavy congestion in the air and on the airport is prevalent in the vicinity of our largest population centers, and it has been necessary to limit by regulation the number of operations at five of our busiest airports.

Greater numbers of aircraft are entering the system. These greater numbers and the widely differing performance capabilities of the aircraft involved continue to intensify problems in the areas of safety, noise, and congestion.

Improvements will be needed in the air traffic control and airport system to provide the greater capability essential to accommodating this growth in aviation. We do not believe, however, that we will find any new major R. & D. breakthroughs or inventions in time to cope with the present air traffic control problem.

We are convinced, therefore, that the essential need is to get on with timely and intelligent application of existing knowledge in the development and operation of the air traffic control system.

We have under review now the findings of the Air Traffic Control Advisory Committee chaired by Mr. Ben Alexander, which under-

took to define the requirements for an air traffic control system adequate for the 1980's and beyond. The Committee concluded that it will be necessary to upgrade the semiautomatic national airspace system (NAS) now being designed to supplant the present manual ATC system if we are to accommodate the aviation growth of the 1970's. It also concluded that with a further upgrading, NAS could meet the traffic needs of the 1980's.

The Committee studies indicated that it will be possible to more than double the capacity of present airports through the use of more precise techniques of instrument landing, surveillance, and air traffic control. Use of scanning beam microwave ILS's will increase the precision of positioning information and permit more efficient use of existing runways.

They also concluded that, by adding computing modules, NAS can be expanded to include spacing, sequency, and conflict prediction and resolution. The Committee further concluded that it will be possible for aircraft to navigate routes near busy terminals more precisely if they utilize VOR/DME area navigators and modern flight directors and are monitored by upgraded radar beacon systems.

The Committee stated that an upgraded NAS eventually would begin to exhibit significant deficiencies, and identified space and computer technologies as offering the greatest potential in the way of increased accuracy and capacity. They noted, however, that both full automation and satellite systems would have to be examined carefully for reliability because of the necessity that they perform virtually without failure. The Committee recommended a research program to run parallel with the upgrading of the NAS and to clarify the issues involved in designing and scheduling the next generation system.

Our principal concern with respect to airports has been to obtain legislation expanding the existing Federal-aid program for airport development. There is a widespread need to expand the capability of existing airports, and, in some areas, we need new airports.

As you know, the President recommended to Congress earlier this year legislation which would commit the Government to a $2.5 billion 10-year airport program. We are pleased that the House has passed a bill similar in many respects to the one proposed by the administration, and we are hopeful that the legislation will receive early attention by the Senate.

Turning to the area of aircraft noise abatement, the Department, along with NASA, has made progress in several areas of research, and we are hopeful that NASA can place more effort in a number of areas of technology to increase the effectiveness of our noise regulatory program.

These include jet, propeller, and rotor noise suppression, operational techniques for noise abatement—particularly in regard to V/STOL aircraft—and sonic boom generation. As you know, we are expanding our research in noise abatement, but we are doing so under the presumption that NASA will be able to continue its participation at least at its present rate. The working relationship between DOT and NASA has been particularly close in the noise field.

Taken on the whole, aviation progress in the United States continues to stay out in front of progress in the rest of the world. Of course, there are specific areas where other countries have gone ahead of us. This is true in the case of the development of a civil supersonic

transport, and it is true with respect to certain STOL and V/STOL aircraft development.

In some cases, foreign countries enjoy the advantage of being able to move ahead in a given area of research and development without feeling compelled, as we do in this country, to evaluate and justify in a cost effectiveness sense each advance we want to attempt in our aviation technology. The approach we follow frequently is difficult to pursue because we are evaluating the unknown and cannot always predict where our efforts will lead, or what benefits we may derive from them.

Some foreign countries, on the other hand, sometimes gain experience very quickly from their prototype programs, and it is conceivable that a larger effort on their part could enable them, as a group, to overcome our lead.

In conclusion, I believe we are making definite progress in getting the most out of our combined R. & D. efforts in DOT and NASA. Both the executive and legislative branches must, however, continue to work to insure that such efforts continue in a cooperative, coordinated way.

As far as the air traffic control system is concerned, it appears from the conclusions drawn by the Aviation Advisory Committee that the NAS program underway in FAA will provide a basis for the development of an ATC system adequate to serve the burgeoning growth of aviation for more than two decades. As far as DOT R. & D. functions are concerned, I believe we need to expand our overall effort beyond the scope of the current basic FAA program to insure that proper emphasis is placed on R. & D. essential to solving aviation problems outside the ATC system and insuring that the aviation system develops in harmony with surface transportation systems.

Mr. Chairman, that concludes my prepared statement and I will be happy to answer any questions.

Mr. HECHLER. Thank you very much, Secretary Beggs, for this presentation.

You notice this morning we are running an unbalanced line to the left here.

Mr. WYDLER. I am ready for the vote.

Mr. PELLY. Of course you've got to realize, Mr. Chairman, that we have a research man on our committee now, in Mr. Goldwater. He did a little personal research in running out of fuel and cracking up and I think he could probably testify here on this very subject.

Mr. WYDLER. Dangers of flying?

Mr. HECHLER. I note, in the latter part of your testimony, you state with great confidence, and I hope it is not overoptimistic, that aviation progress in the United States continues to stay out in front of progress in the rest of the world.

It is with some apprehension that this committee starts these hearings, because we are very much concerned that the future may not be as bright as you assess the present.

Secretary BEGGS. Mr. Chairman, I did not mean that statement to indicate that I do not have a concern here. I have a great concern. The statement stands as I put it, that I think we are still in the lead.

However, a number of countries are closing that lead very rapidly, and I am very much concerned at what I see in the air transport area. In transport aircraft we see a number of foreign countries moving into

the market very rapidly and with great vigor. Indeed, the Soviet Union is starting to make moves throughout the world to sell their transport aircraft to a number of countries, and this is of great concern, and I think it is a worrisome thing.

It is particularly worrisome when it is projected against the background of the development of civil aviation transports in this country, where I think in some areas we have rested on our oars and have not done the research and development that perhaps we should have done in order to maintain our lead.

Mr. HECHLER. I am glad you clarified that, because your statement seems to me to contain a note of complacency that disturbs me. And I recall last year when Dr. Paine, the NASA Administrator, appeared before this committee, the first question I asked him was "What emphasis is the Soviet Union placing on aeronautics?" and he sounded the alarm signal quite clearly at the time.

Would you care to elaborate anything on that point?

Secretary BEGGS. Well, we do see the Soviet Union making strong efforts to sell their supersonic transport, the Tupelov transport, in a number of countries, and from the point of view of being able to barter with other countries, they have some very large advantages in selling this airplane.

For example, they have one of the great undeveloped air routes, the route across Siberia, which could be bargained in the sale of aircraft. We also see them trying to make arrangements in Western Europe, most particularly in Italy, to sell some of their subsonic jets.

It also appears that in the area of the development of new transports and improved transports they have a very vigorous research and development program going. They have several design institutes devoted to the research and development of transport aircraft, and there is no question but that they are making very rapid progress.

Mr. HECHLER. I have several other questions to pose, but I would like to yield to other members of the committee at this point.

Mr. Pelly.

Mr. PELLY. Mr. Chairman, I am moved to remark that I am only sorry the Secretary's statement which he just made wasn't made before the recent vote on the American supersonic plane. We needed a few statements like that to impress some of my reactionary friends who didn't feel the priority of the American SST.

I would like to hope that possibly that same statement will reach some of the Members of the Senate as they consider that $95 million appropriation, so as to continue our research in this field. And I can think of particularly one or two over in the other body that right now should be thinking in terms of the Russian competition, which is of course not responsive to the economic factors that we are.

Mr. Secretary, on page 7 you referred to the recently passed Federal aid program for airport development. How many airfields in the country today are set up to take care of the 747?

Secretary BEGGS. Well, the short answer to that question, I think, Mr. Pelly, is none, but I would say that some of them are better able to handle the 747 than others. Certainly only a relatively small minority of civil airports are in a position to really do justice with respect to the 747.

Mr. PELLY. Will that particular airport act aid these communities in providing for the latest developments?

Secretary BEGGS. It will allow us to provide aid to airports on a much greater scale than we do today.

But I am afraid that bringing airport facilities up to the level of air transport technology is going to be a slow process, and for a while the 747's are going to have a very bad impact on those airport facilities. There are going to be jams like we have probably not seen before.

Mr. PELLY. Well, if you bring in anywhere from three to five hundred people into an airport, doesn't that lessen the number of landings?

Secretary BEGGS. Yes, sir; we anticipate that it will very materially help the problem of air congestion around airports in that it will decrease the number of planes coming in.

Mr. PELLY. And isn't it true that the 747 has benefited by the noise abatement research program and will not have actually as much noise as the experimental 747?

Secretary BEGGS. Indeed it will. It will be a very quiet airplane indeed.

Mr. PELLY. I have done a little research on that, because the experimental 747 has been flying over my home in Seattle and I don't find it objectionable at all.

Mr. WYDLER. How high is it?

Mr. PELLY. I am sure my friend, Mr. Wydler, is going to appreciate that fact before too long. He is the one that was calling for more research in noise abatement, when actually witnesses before this committee were resisting it.

Moving on, however, I want to refer, on page 8, when you mentioned the foreign competition. You were talking about, and its SST. Isn't it a fact that what we are talking about really is a plane, a transport plane for the 1980's?

Secretary BEGGS. Yes, sir.

Mr. PELLY. And in this connection we have to do our research work now in order to ascertain the needs in the way of airports and noise factors and other beneficial effects that can come out of research before, we will say, 1980?

Secretary BEGGS. That is correct. Our supersonic is, of course, a larger and faster machine than the designs by either the British-French consortium or the Soviets, and it will be a much improved aircraft, we believe, in terms of noise. It will be a much less noisy machine than either of the competitors.

Mr. PELLY. In other words, it will only fly at supersonic speeds over water?

Secretary BEGGS. Well, as far as the sonic boom is concerned, the President stated that it will fly supersonically only over uninhabited areas, water and arctic areas.

Mr. PELLY. But the actual noise coming into a field will be actually less than the other?

Secretary BEGGS. The noise pattern of this aircraft insofar as community noise is concerned, may be less than that of the current generation of subsonic aircraft. The one area in which it will be appreciably noisier is sideline noise, and here, according to studies of the

airfields that will be used primarily by this aircraft, we do not think this will be an objectionable feature.

That is to say, it will generate more noise on the sideline, but less noise over the community.

Mr. PELLY. Well, actually what we are talking about, though, is the first generation.

Secretary BEGGS. Yes, sir.

Mr. PELLY. You expect improvement on the next generation of SST's, that tremendous improvement will be made?

Secretary BEGGS. (Nods).

Mr. PELLY. When we actually get into the production of these planes on a regular, standard basis, do you expect a much more satisfactory plane as far as the noise and other factors are concerned?

Secretary BEGGS. Yes, sir. We are talking about an airplane that will go into production in about the 1975–1976 time period. By that time I expect that much of the noise research that is being done both by the FAA and NASA will have given us some material benefit in terms of noise suppression technology, and possibly in basic low-noise engine designs.

So by 1975–1976 I would expect that there will be technology available that will very, very materially reduce the noise output of supersonic aircraft, along with all the subsonics.

Mr. PELLY. You don't mind if I take excerpts of your statement today and send to my colleagues here, so that we have a better chance of retaining our superior position as far as the manufacture of air transport planes, do you?

Secretary BEGGS. Not at all, sir. I would welcome that.

Mr. PELLY. Thank you. It is a very fine statement.

Mr. HECHLER. Mr. Wydler.

Mr. WYDLER. Thanks, Mr. Chairman.

First, Mr. Beggs, I want to say I think the Government is lucky to have a man such as yourself in the position you hold, because of your background, and what you know about this whole problem from all the points of view that are necessary to bring our interests together here.

So I am delighted with your appointment.

Secretary BEGGS. Thank you for that.

Mr. WYDLER. I want to play the devil's advocate with you for a few minutes on the question of the SST, because I want to give you——

Mr. PELLY. You did that last year.

Mr. WYDLER. I want to ask you the questions that the people are asking me as their representative, and as a person that pays the bills for them, whether they like it or not.

They are asking me some questions which I find difficult to deal with. Maybe you can give me some answers I can't think of. One of the questions they ask me is what exactly does the United States of America get out of the SST?

Secretary BEGGS. Well, I think we get a number——

Mr. WYDLER. We can understand the interests of the plane manufacturers and the airlines, of course, but I think what the people are really interested in is understanding what do they and our Government get out of this project?

Secretary BEGGS. I think it is a very good question, and I think there is a very good answer to it. We benefit, that is the United States bene-

fits, in a number of ways. First and I think most important, although this perhaps can't be quantified too well, this is the singlemost advanced aeronautical technology program underway in this country.

I don't think we realize how much this Nation draws on the technology developed in our advanced programs. And the continuation of an advanced program such as this I think is vital for the future.

I had the privilege of visiting Japan several months back and one of the comments that the Japanese officials made to me, in casual conversation, but I think it is a meaningful comment, was that we in the United States don't really realize how important our position in advanced technology is to the sale of products around the world.

The point they were making was that in a real sense we are able to obtain higher prices for a number of our products unrelated to the advanced technology, simply because of the fact that people throughout the world look on those products as being better because of the image we have in advanced technology.

I think it is a very material benefit that we get out of these programs. I agree we can't quantify that.

Mr. WYDLER. That would be a very good argument, for example, to say we should continue with the space program, but I don't see how you would relate that particularly to aircraft. It would seem to me the leading proof of the general use of technology would be our space program in that sense that you are using it now.

You can hardly use that as a justification for aircraft.

Secretary BEGGS. I think the two are not unrelated, but I do think they are different. The SST is the only really advanced technology program we have underway and while the space program—and I am for that, too, don't misunderstand me. It is a different kind of a thing, if you will. Aeronautics. I think is a very tangible thing to people because it is around them all the time. The space spectaculars come along only once in every several months.

But in my view you have got to have both, and both contribute to this image I was referring to just a few minutes ago. But let me go on.

Secondly, I think that maintaining the preeminence of this country in civil air transport is a very vital factor in both the financial position that the United States has abroad, and also in the prestige that we maintain abroad in our foreign policy. To be able to say that 80 or 90 percent of the transport aircraft flying in world commerce are built by the United States I think is saying a great deal. To give up that position without going to the next generation of aircraft I think would be disastrous for our total, overall policy vis-a-vis the rest of the world.

In a more tangible area, this Nation has realized a balance of payments, a favorable balance of payments, from the sale of air transports in the world market that approaches three-quarters of a billion to a billion dollars a year, and this has been one of the bright spots in the sales of American products abroad.

Mr. WYDLER. Has that ever been offset against the number of Americans that use these aircraft to fly to the foreign countries and drain the dollars away?

Secretary BEGGS. Well, there is an argument about foreign travel, which I would like to touch on in just a minute.

The Secretary of Commerce recently alluded to this favorable balance given to us by our sales of transports and said the air transport industry is the one bright spot in our balance-of-payments picture. And indeed this is an area where I think this country can compete on favorable terms. It is a high technology product, and this tends to be an area where Americans compete very effectively.

With respect to this question about the offsetting travel balance, it is my—we discussed this at great length in the Department in reaching this decision. It is my view that Americans are going to travel, and they are going to travel as a general rule in the most convenient and fast mode. They have done this for generations. It seems inconceivable to me that if the foreign airlines are flying either Concordes or Tupelov transports, Americans will not travel on them, because they will be faster and they will be more convenient. And the idea of sort of closing our doors to that kind of travel, I think is not a real prospect.

So if Americans don't travel on an American supersonic, they will travel on a European or a Soviet supersonic.

Further, I am not real sure that this travel balance argument really holds a great deal of water. Its basis is that with the introduction of the subsonic jets, there was a tremendous increase in foreign travel. The reason for that, of course, is the subsonic jets made it much more convenient to get to Europe.

There was a resulting very large increase in the number of Americans spending money in Europe. But in recent years we have seen an upsurge in the amount of European travel in the United States, and as the Western world, as the Europeans become more affluent and as the Japanese become more affluent, I think you are going to see a great deal more travel on their part in an offsetting way against the travel that we are doing.

Mr. WYDLER. Just let me ask you this question: I think what the people might object to the most in this, and when I say "the people" I mean the average citizen, 's the way this whole thing is being financed or is proposed to be financed.

Mr. HECHLER. Will the gentleman yield quite briefly?

Mr. WYDLER. Yes.

Mr. HECHLER. I am quite sensitive on the question of the jurisdiction of this committee with relation to interstate and foreign commerce. We obviously can't make decisions in this subcommittee or in the full committee on the substantive question of whether to go ahead with the supersonic transport.

I would hope we would confine these hearings perhaps a little bit more to what can be done in the future of aeronautical research.

I always hesitate to interrupt a committee member on that basis, but I am advised on higher authority that the jurisdiction of this committee and the charter of these hearings may not extend to the areas that we appear to be getting into now.

Mr. WYDLER. All right. Well, I will defer to the Chairman's wishes on the matter, because I agree that we can't solve this here. It was just the opportunity to talk to Mr. Beggs about these problems that seemed to me very important, and as Mr. Pelly felt it was so helpful to him on one side of the issue, that I thought we might develop the other side too.

Mr. PELLY. I thought you were quite helpful, too, in the questions you asked.

Mr. WYDLER. Talking about the technical end of the problem, what I am particularly interested in, from your statement, is of course the problem of the jet noise and what it means to the future of aviation. And it is a technical problem certainly. As we are finding out, it can be technically solved when the effort is made.

Now for years I have been hearing that, for example, we couldn't use one of the most feasible methods it seemed to me of reducing jet noise on landings, and that was through increasing the degree of approach pattern to the landing strip.

(Secretary Beggs nods.)

Mr. WYDLER. Which as I understood by going to a 6° angle, we would immediately cut jet noise in half, which would be an almost incredible improvement in the problem on landings.

(Secretary Beggs nods.)

Mr. WYDLER. But I was told for one reason or another this couldn't be done because we didn't have this piece of equipment or that piece of equipment. But I have recently been told by a company that happens to come from Long Island—that is really irrelevant where they come from, but they were talking to me about something else. We have the equipment that will do it right now, and they say will do it safer than present aircraft, and would do it under any weather conditions, which would help you on your traffic control problem.

I think it is the same thing you are talking about on page 6 of your statement, where you talk about the scanning beam, microwave ILS's. Is this what they are talking about?

Secretary BEGGS. I don't think so. It may be, but I don't think so. The problem that we ran into on the steep descent procedure was largely in the cockpit.

Mr. WYDLER. Yes, I realize there is a human problem involved.

Secretary BEGGS. The pilots were a little unsure that they wanted to fly this kind of glide slope without having more electronic aids to give them the assurance that they wouldn't fly that steep glide slope right into the ground, which of course would be catastrophic.

Actually, we haven't abandoned this at all. We are running further tests and we hope one of these days to be able to certify it for use.

Mr. WYDLER. I know that. You see, I have been in Congress now for about—this is my 7th year, and I have been told that for the last 5—at least 4, maybe 5 years, that we are hoping someday we will get around to that.

Secretary BEGGS. Mr. Wydler, one of the things that bothers me in the job I have had is that things do take so much time. As a matter of fact, I think I made a statement here last year about a study that we were going to have out last spring, and it turns out that is going to be a year late.

It does turn out that it takes an awful long time. We are trying to improve the schedules on some of these things. But one of the problems is that you do have a number of individuals involved in a development project such as a steep descent approach who have to be satisfied, and quite properly so, I think, under our system. The airport operators have to be convinced, the pilots and their unions have to be convinced, and the airlines, of course, who have to buy the additional equipment, have to be convinced that it is a good investment.

While I think that this particular one could perhaps have moved a little faster than it has, it did require convincing a lot of people. I think people are becoming convinced that it is a good idea now. I think they are beginning——

Mr. WYDLER. There are a number of features in that. The one that surprised me is that I was told most recently by people from your Department that it was safer. And I had always been led to believe that was the big problem with it, that it was entering new elements of risk into the passengers' lives.

You know we are always told that. Whenever we have something uneconomical for the airlines, they throw up the specter "This is risky for the passengers, and we have to protect them." We stack the passengers up for hours on end and fly them in holding patterns, but the airlines don't seem to worry, or the risk to the passengers when that happens is not raised.

So I am not concerned about that any more. But I was told by the people in your Department that it was probably the safer system of landing, and it would reduce the noise. So I am beginning to get less patient about the particular matter.

I have written you letters. I have sent you the material from the company involved, who made the claims.

Secretary BEGGS. Yes, sir.

Mr. WYDLER. If they are not true, I would like to see them refuted. I don't care who builds the equipment. But I wish somebody would get on with putting this particular procedure into effect, which really would have a dramatic improvement for a lot of people living near airports in the country.

You say that we are going to have less flights with the 747. How many flights are they going to reduce with the introduction of the first 747? Does anyone have the schedules?

Secretary BEGGS. That I do not know, because the schedules have not been promulgated yet, although the aircraft does carry upward of 400 passengers, depending on the configuration. Clearly if you can replace four aircraft or thereabout, which are carrying 100 passengers each with one of these, you are going to have fewer flights. In the long run——

Mr. WYDLER. Who is going to see to that? That is what I am trying to find out. Who is going to see you have less flights? Wouldn't the four airlines still want to fly their four aircraft?

Secretary BEGGS. Not if they can't generate the traffic.

Now, in the long run, I believe that the number of flights will build up again because the growth of civil air transport is continuing at about the same rate that we have observed over the past decade. That has been at about a 10 to 15 percent compounded rate. So it will double again and triple again probably in the next decade.

So in that time I expect there will be the same number of air transport flights; that is, at the end of the decade of the seventies as there are today.

Mr. WYDLER. Did you find that the scheduling limitations that you put in so far have worked well?

Secretary BEGGS. Yes, they have worked quite well insofar as the traveling public is concerned. The area where there is still a good deal of complaint is from the business aircraft sector and I think they have

a legitimate complaint because the number of reservations available to them is very limited and they have had trouble getting into these five airports.

And I think we must do something about that. But I should point out to you that this problem was acute last year. You are aware of the fact, by your statements, that we had holding patterns in heavy use for hours and we simply had to do something.

Now it is going to take several years to increase the capacity of the system to the point where we can remove those restrictions, but I think we can start to open them up in a year or two. We will be able to open them up in a year or two, so as to provide some relief to the other sectors of the aviation community.

The problem here is clearly technical, and we are behind.

Mr. WYDLER. One more question, Mr. Chairman, if you don't mind. I know I have asked many questions here. But it seems to me another key question that we are arriving at, and are deciding in the area of transportation, is this one, and this is just how far from the center of the city can an airport be?

I am talking about a major airport. And this is a question you are going to have to answer, it appears, in practically all the major urban areas of our country in the near future. I am curious whether you have done any thinking about that and if you have, what answers you have arrived at.

How far can you go from the urban center with the airport before it becomes either economically or for some other reason impractical or not feasible? Has there been any thinking done in this area?

Secretary BEGGS. Yes, sir, there has been a lot of thinking and several studies on that subject, a number of them very inconclusive, but there are some—well, we are beginning to get some vectors on what you can do.

The problem of airport access of course is one that is still unsolved and one that we are wrestling with all the time in the Department. We feel that somehow you have to come up—at the time you design these large regional airports, you have to come up with a good system of airport access.

It would appear from the studies that have been done that an airport can be as far out as in the order of a half to three-quarters of an hour traveltime for the person who wants to use it, and with some schemes that I have——

Mr. WYDLER. You mean by helicopter or how?

Secretary BEGGS. That is what I am saying, by some scheme of ground transportation. For example, we have looked at tracked air cushion vehicles that have a potential for attaining speeds upward of 150 to 200 miles per hour, and we have looked at other kinds of tracked vehicles or vehicles that might run on rubber but wouldn't use the tires for traction that could run upward of 100 to 120 miles per hour.

With these kinds of speeds and a system of this sort that is economical, and by "economical" we are looking at costs for installation of the system of less than $1 million a mile, perhaps in the order of half a million to a million dollars a mile—on this basis you could probably go out 50 miles or more and still be in an area where access would be adequate.

Now you would have to design a system around that. You couldn't just look at it as an airport access problem. You would have to provide some kind of parking facility for the users in an area where they could get on the public transportation and then get to the airport relatively quickly.

Mr. WYDLER. If I asked you a very hard question: In my area, New York, some people are talking about putting an airport out in my general area in Long Island, about 80 miles from New York City. I think it is probably as close to New Haven when they finish with it as it is to New York. In which event, I just wonder is that practical? Because it is not a bad idea in some ways. If say they want to build it on the water, which seems to be the coming modern approach to airports—everybody has the problem to start thinking about sticking them in the middle of a lake or the sound, in our case.

I am just wondering about it from the point of view of distance. I think otherwise it probably could become economically not feasible. I think the cost of building it—I think you could get that back. But I am just wondering about it from the point of view of feasibility as far as distance from the main target area.

Is that considered within the realm of reason or not? Is it something worth discussing or isn't it?

Secretary BEGGS. I think it is, particularly in the New York area, where we have so much difficulty in finding a fourth site for a jet port. Eighty miles I think gets into the edge of what we can do for the commuter, but I don't think it is too far out considering that in many cases it takes an hour or so to get in from Kennedy.

So from that point of view, I guess—with a suitable access system, I guess you could get them into downtown Manhattan in an hour.

Mr. WYDLER. I suppose the answer to this is the future will see these urban areas becoming larger and larger, and these airports in effect will be serving regions rather than the urban center and the urban center itself will not become that important. I can see that, too.

Secretary BEGGS. We see two things. We see the regional airport concept, which I think has merit in a number of areas in the country. We would also like to do a little demonstration work and try to develop the concept of the V/STOL aircraft to take some of the pressure off the larger jet ports. And I think it has potential for the urban areas, from the standpoint of trying to take the pressure off and increase the ability of the existing airport complex to serve the area.

Mr. WYDLER. Thank you.

Thank you, Mr. Chairman.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. Thank you, Mr. Chairman.

Mr. Beggs, I am a private pilot. One afternoon I took off from Burbank and headed for Long Beach about 50 miles, and it was a usual Los Angeles day, sort of smoggy. The visibility was marginal. It is the custom for me to contact the approach control, air traffic control for surveillance. I was unable to do this during my journey from Burbank to Long Beach.

I had three near miss collisions. Now, the point that I make before I ask the question is that there are approximately 118,000 aircraft flying around this country today, of which only approximately 2,200 are commercial aircraft, the rest being general aviation. On top of

this there are approximately 600,000 private pilots, or pilots that are flying these aircraft.

In all this research and all this studying on air traffic control and new regulations what is being done about the general aviation pilot, the guy who is a weekend pilot, the fellow who flies around in a small airplane? How can the private pilot cope with the new technology, the new advances that are being applied, the new regulations promulgated. What about the cost factors for the private pilot to keep up to date on these new regulations and the new technologies he will more than likely have to have in his airplane to approach air traffic control for surveillance?

Secretary BEGGS. Well, you pinpointed the problem and perhaps the solution. In my view the solution is positive control in the high traffic areas. And here it is a question I think of equipping the general aviation craft with the proper equipment to plug into the system.

Now we do think that you will be—in fact, we can now provide beacon systems for under $1,000 installed in the private aircraft, and this will go a long way toward enabling the small planes to plug into our national air space system.

Mr. GOLDWATER. You mean like a transponder?

Secretary BEGGS. Yes, transponder. Once we get ourselves equipped throughout the country to apply this system broadly, I think we will have a system in place that has the capability, until we reach the capacity of that system, of maintaining positive control in the high density areas. Beyond that, I think we have got a lot of work to do.

Mr. GOLDWATER. Does a lot of this have to do with the equipment and the manpower that you need at the centers?

Secretary BEGGS. Both. The equipment is currently being produced and we have not bought it in sufficient quantity to equip all the centers throughout the country, that is, all the high density centers throughout the country, but with the moneys that we have requested in the Airport Airways Expansion Act, I think the projection is we will be able to equip everything in the country in a matter of about 8 years.

Now we think this system will be good through the 1980's, as I said in my testimony. The projections now, with the improvements that we can work into that system as we go along, will enable it to have a life through the 1980's. In the scheme of things that is not a very long life. It would be less than a 20-year life from the time we get the whole system installed.

So I think we have got a lot of homework to do in technology in order to make the system more automated and do what you are asking, that is to give the private pilots who comprise the fastest growing sector in this aviation community, a chance to continue flying in the high density areas, because I think there is a very real danger now that somewhere along the line it will simply get too dangerous in some of these areas for them to fly.

Mr. GOLDWATER. I have just one quick question, if I could.

Secretary BEGGS. Sure.

Mr. GOLDWATER. I have to compliment Jack Shaffer, the FAA, and the whole staff for the work they have done in promoting that type of project on congestion.

You say if this money is appropriated, it will take 8 years. What can be done right now to say ease the burden on the air traffic controller?

Secretary BEGGS. Well, there are a couple of things that we have initiated. One of the problems with the air traffic control situation is that in the high density centers, again, the controller is under extreme pressure. Relatively little has been done to study the man-machine relationship, the human engineering, that probably should have been done a number of years ago in order to ease his burden.

You have been in an air traffic control center. One of the things that strikes you is that these men are sitting on one another's lap as they work the system. With what we know from a great amount of research and development, both in the Department of Defense and in the National Aeronautics and Space Administration, we can do something immediately. And I have General Lundquist working on that problem right now, to bring some experts in to take a quick look at that problem, and I think within a very few months we can start seeing some material benefits in that area.

Beyond that, the new equipment will ease the burden. The controllers who have used the new arts system are quite impressed by the way it helps them do their jobs. There is a greater easing of the pressure on them than heretofore.

But with all that, we are going to need more controllers.

Mr. GOLDWATER. Why wouldn't you recommend cutting down on commercial flying?

Secretary BEGGS. It is my view that while the load factors this year are hovering around the 50 percent mark—and this is a low point I think in the cycle—I see those load factors going back up over the next couple of years. It is my belief that the number of flights in the high density areas in particular are not excessive at this point, for the development of the air transport industry. If we continue to experience load factors in the 50 percent range for the next year or two, then I think we ought to give serious consideration to the schedules, and give some thought to doing just what you say.

But I don't think the current situation warrants that.

Civil aviation has gone through these cycles several times in the past and it has always been a very temporary thing, then the load factors have increased very quickly.

Mr. WYDLER. Would the gentleman yield, just for my understanding?

I found two statements you made hard to understand. You said you expected us to have less airplanes flying with the 747's, and then you said we are going to need controllers. One of those statements doesn't follow from the other.

Secretary BEGGS. The statement I made about 747's relates to the air transports.

Mr. WYDLER. Right.

Secretary BEGGS. These, of course—as Mr. Goldwater has pointed out—constitute, relatively speaking, a small number of the aircraft flying. There are in the order of 2,200 to 2,500 civil air transports in the fleet today, whereas there are 115,000 to 120,000 general aviation craft. At any particular hour of the flying day there may be upwards of 12,000 aircraft in the air. Clearly a very small percentage of them will be air transports. And our problem is related to that 12,000 aircraft that are flying, and not simply to the 1,000 or so air transports that may be in the air at any one time.

Mr. HECHLER. Would the gentleman yield at that point? Mr. Goldwater?

Mr. GOLDWATER. Yes, sir.

Mr. HECHLER. My recollection is that the FAA predicted when the large conventional jets were introduced that there would be fewer flights, is that correct?

Secretary BEGGS. I believe they did, yes, sir.

Mr. HECHLER. And that didn't exactly work out, did it?

Secretary BEGGS. No, that didn't work out because when the subsonic jets were introduced, the use of the system increased drastically because of the convenience of the subsonic jets in moving people around, and the number traveling, that is the traveling public increased more than enough to take up the slack. Incidentally, at the time that they were introduced, the load factors were again relatively low and they grew very nicely over the next few years and more than took up the slack. And as I have said before, I anticipate the same thing will happen with the 747 in time, and perhaps in a shorter time than we are projecting, but it is our belief that the number of passengers will triple in the next decade or so.

There again, the number of 747's flying perhaps will equal the number we have flying today. But I have got to go along with the current projection of the FAA, in their belief that with the introduction of the 747 we will have fewer flights. And I should point out that this projection is related to high density areas such as New York, Chicago, Washington, San Francisco, Los Angeles, Dallas-Fort Worth, and so forth, because it is in these areas that we have real trouble.

I think when the 747 starts flying, it will ease that problem. Now it may not ease the overall problem in the system. There may be, indeed, in a very short time the same number of air transports flying.

Mr. HECHLER. Mr. Goldwater?

Mr. GOLDWATER. I am through.

Mr. HECHLER. I just wanted to follow up one observation that Mr. Wydler made. It has always puzzled me that in measuring the distance from center city to an airport you always assume that everybody is going to start from the corner of one downtown street corner, which is obviously not true. You have got to measure this, it seems to me, in terms of your highway system, and in terms of distribution of population and get some other formula for measuring how far people have to go to airports.

But you say, "Oh, they have to go 50 miles to 42d Street and Broadway!"

Secretary BEGGS. There was a study, Mr. Chairman, done 2 or 3 years ago on this question with respect to the airports in the New York area—where the people wanted to go and where they came from—and it turned out, as you point out, that relatively few of them, I think in the order of 30 percent or so, really wanted to go into downtown Manhattan. Most of them were going elsewhere.

And when you look at where they came from, a similar situation was true, that is a relatively small percentage of them came from the center city and most of them came from the suburbs, from Connecticut, New Jersey, Long Island, or what have you. So there is a very complex problem in trying to configure an airport access system that will truly serve the traveling public, because as you say, the traveling public is

not going to start from the same place and they are not going to come to some corner in the center of the city in order to get on.

That was the intent of the comment I made. When you consider airport access, you have to consider it as a system and I think you have to provide adequate parking at various places along the route and you have to lay the route out in such a way that it is accessible to the majority of the traveling public. Otherwise they won't use it, and you will be back into the same kind of problem that we have today, with crowded airport parking lots and poeple complaining that they can't get to the airport when they need to.

Mr. HECHLER. I would like to ask several more questions before I yield to Mr. Helstoski.

(Mr. Helstoski nods.)

Mr. HECHLER. Mr. Ben Alexander, the chairman of the Air Traffic Control Advisory Committee, came before our committee last year, as you know, and gave us some preliminary figures as to the direction in which this advisory committee was going to go.

Now that this study has been completed and is under review, I wonder if you would submit the study or its conclusions for inclusion in the hearings?

Secretary BEGGS. Yes, sir; we can. We did release it last Wednesday and we would be pleased to submit it.

(Because of the volume of material submitted included are summary and recommendations only of this report, as follows:)

I. INTRODUCTION

The Department of Transportation Air Traffic Control Advisory Committee[1] was formed in the summer of 1968 for the purpose of recommending an ATC system for the 1980s and beyond. The Committee's technical staff—made up of some 150 individuals, full- and part-time from all segments of the aviation industry—studied the most critical problem areas. The Committee members met monthly to review accomplishments and guide the ongoing work. In addition to drawing on the FAA, NASA, DOD, and the aviation community for technical staff, the Committee maintained liaison with various aviation organizations, including the military, NASA, AIA, ALPA, AOCI, AOPA, ATA, EIA, NBAA, NPA, and others. Without this broad participation at both the technical and policy levels, the work described in this report could not have been accomplished.

The Committee concentrated on control of aircraft through the airspace, from takeoff to landing. Emphasis was placed on the denser portions of the airspace where the danger of midair collisions and the need for efficient use of scarce resources (principally runways and terminal airspace) make sophisticated air traffic control mandatory if safety is to be assured without sacrifice of capacity and without unacceptable delays or interference with freedom of flight. Airports were included in the study insofar as they strongly interact with air traffic control. The Committee's primary concern was with efficient use of runways, while taxiways, ramps, and other facilities were considered only to the extent necessary to understand airport efficiency and real estate requirements. No work was done on airport access. As it became clear that aircraft noise abatement can frequently be obtained by proper terminal routes and procedures, considerable effort was placed on the subject of noise reduction which may be critical to community acceptance of high capacity airports.

The conclusions reached on air traffic control for the 1980s and 1990s assume that runway capacity in the dense traffic areas will be provided. This is our present severe bottleneck, and the improvements to the air traffic control system discussed in this report will not be significant unless the airport (runway) problems are also resolved.

[1] Committee members, affiliations, and titles are listed in Appendix A.

The Committee elected to place minimal effort on over ocean air traffic control and communications in view of the apparent adequacy of existing technology and the straightforward nature of the problems.

The Committee postulated a fundamental requirement that the air traffic control system of the future should not significantly constrain the growth of aviation.[2] The specific requirements which derive from this are performance and cost characteristics which permit all of the users to maintain activity levels close to what they would have been if the cost were much less or the performance much greater. While this approach to establishing system requirements has its limitations, it has proved workable and equitable at this stage of aviation growth.

Air traffic control is now ending its second generation.[3] The present manual system is soon to be supplanted by the semi-automatic Third Generation System, which follows guidelines recommended by Project Beacon in 1961.

In order to understand the problems of transitioning to a new system in the 1980s, the Committee studied the performance of the Third Generation with the projected traffic loads. It became apparent that the Third Generation System, as presently planned, must be substantially upgraded if it is even to accommodate the aviation growth of the 1970s. Studies of feasible modifications show that it is entirely reasonable to select an upgrading program which can greatly extend its useful life. Moreover, this upgraded Third Generation System, in comparison with alternative approaches, appears capable of providing the capacity needed with fewer compatibility problems, less technical risk, and at lower cost. By implementing these modifications progressively, it should be possible to accommodate the traffic as now projected into the 1990s. The Committee strongly urges this path be followed, and most of this report is concerned with upgrading the Third Generation System. Near the end of the century, a Fourth Generation System may be needed. The report identifies major innovations that such a system might include and suggests fundamental studies needed in advance of any development effort.

While the Committee is reccommending specific system characteristics and is proposing a number of high priority system engineering and development programs, it has not attempted detailed designs, nor has it considered specific deployment plans. Nevertheless, it is clear that the approach recommended will require an investment of several billion dollars during the 1970s in air traffic control development and facilities. *Additional billions will be needed in the* 1970s for airport improvement and new construction if the demand is to be accommodated.

The Committee is concerned that the system recommended by Project Beacon in 1961 will not be completed before 1973. An early review is urged to determine the new organizational and contractual arrangements necessary to ensure the timely completion of a program of the magnitude and urgent national priority recommended in this report.

2. Summary

THE CRISIS

Air traffic is in crisis. The crisis now manifest at a few high density hubs is the direct result of the failure of airports and air traffic control (ATC) capacity to keep up with the growth of the aviation industry. With proper leadership, funds, a sense of common purpose in the aviation community, and steps taken to promote coexistence between airports and their neighbors, this deficit can be eliminated through intelligent application of recent advances in aeronautics, electronics, and computer science. Unless strong measures are taken, forces presently in motion will blight the growth of American aviation.

The demand for all categories of aviation will maintain its high growth rate unless further constrained by an inadequate air traffic system. The various national indices of aviation activity are predicted to at least double by 1980 (with respect to 1968) and to double again by 1995. Five airports now operate at saturation during peak hours. This number will rise to twenty by 1980 unless present expansion plans are accelerated. The demand for air traffic control serv-

[2] This does not mean that the Committee favors implementing ATC improvements to meet peak demands independent of their costs or the users' willingness to pay, nor does it imply that the Committee rejects the use of differential pricing or route and scheduling restrictions to obtain maximum benefit from the ATC and airport systems at various stages of their development. These questions of policy are considered to be outside of the Committee's charter.

[3] See Appendix B for a description of the Second and Third Generation Systems.

ice will rise even faster than activity in general. Overall, the demand for ATC service is estimated to almost treble by 1980 and to treble again by 1995.

In light of this projected demand, the Committee sees three critical problems which urgently require solutions if aviation growth is to be accommodated:

The shortage of terminal capacity;
The need for new means of assuring separation;
The limited capacity and increasing cost of ATC.

UPGRADING THE THIRD GENERATION SYSTEM

The semi-automatic Third Generation ATC System, originally recommended by Project Beacon in 1961, is now being implemented. It will initially become operational in 1971 and will be in widespread use by 1973. Due to the slow pace of implementation and unforeseen aviation growth, it now requires major modification if it is to solve the crucial problems that the Committee foresees for the late 1970s and beyond.

Terminal capacity

The airport plant at a number of dense hubs is often saturated by the present demand at peak hours. There will continue to be popular resistance to construction of new airports in major urban areas due to their high costs, the diffuse distribution of the benefits of aviation activity, resistance to increased noise, and political fragmentation. As a consequence, it is not reasonable to expect additional urban airports sufficient in number to satisfy the forecast demand even if increased use of V/STOL is taken into account. Major improvements in current airport capacity must be achieved. For public acceptance, this should be accomplished without increasing perceived aircraft noise.

Committee studies show that it is possible to more than double the capacity of present airports. By the use of newer techniques of instrument landing, surveillance, and air traffic control, additional runways can be brought safely into use and all runways made to operate at higher capacity. The same principles can be applied to new airport construction to provide greater capacity than airports as presently designed.

The dual lane runway provides a 40% increase in capacity using present separation standards. Automation beyond that presently planned would increase runway capacity by an additional 30%. Decreasing aircraft longitudinal separation to two miles could provide still another 40% increase in capacity. Thus, dual lanes, automation, and decreased separation could provide more than a twofold increase in runway capacity. Furthermore, additional capacity can be provided by utilizing airport acreage more efficiently by decreasing the 5000′ separation between independent IFR runways. The Committee believes it will be possible to safely reduce this separation between runways to 2500 feet and the final spacing on approach to two miles. This will require (1) an improved landing aid, such as the scanning beam microwave ILS, and (2) provisions for precise monitoring and data linked commands in case of blunders. These requirements, along with increased terminal automation, are included in the upgraded Third Generation System. While procedural techniques can probably be devised to permit the recommended separations despite wake turbulence, means may be required for predicting, sensing, or dissipating dangerous wake turbulence. The Committee's wake turbulence dissipation studies have shown promise.

Curved routes to airports, made possible by a scanning beam microwave instrument landing system, can reduce public discomfort due to aircraft noise. Moreover, the quiet nacelle program has shown encouraging results. By incorporating low noise routing plus engine quieting, a preliminary study of Kennedy airport indicated noise could be reduced even though traffic was doubled.

Separation

The current use of radar and ATCRBS [4] data to assure separation has largely eliminated collisions between aircraft when both are under radar control. In recent years, however, collisions between air carriers under control and uncontrolled aircraft have averaged more than two per year. Since the likelihood of such collisions rises about as the square of the aircraft population, measures

[4] Air Traffic Control Radar Beacon System.

beyond the present use of "see-and-avoid" in portions of "Mixed Airspace"[5] will become mandatory by 1980. Committee studies predict an air carrier-general aviation collision rate of 10 per year in 1980 in Mixed Airspace unless changes are made. Furthermore, the collision rate between uncontrolled general aviation aircraft (33 in 1968) will also grow rapidly unless improved means of assuring separation are provided.

The Committee believes it is now feasible to largely overcome the midair collision problem in portions of the airspace under surveillance without significantly restricting freedom of flight. The strongly preferred approach to this lies in automating and making more precise the air traffic advisory service. Additional protection may be available through cockpit visibility improvements, conspicuity enhancement, and possibly PWI or CAS[6] devices.

By means of a data acquisitiin system which reliably and accurately provides the ATC Center with identity, position, and altitude information on all aircraft within designated portions of the airspace, the ATC computer, through a data link, can automatically advise aircraft of threats due to other aircraft, weather, airspace boundaries, and surface obstacles. In addition, instead of merely advising of threats, the computer can generate commands for appropriate evasive maneuvers. This process is called Intermittent Positive Control (IPC).

Under IPC, conflicts between aircraft under surveillance, controlled or uncontrolled, would be predicted, safe maneuvers calculated, and appropriate commands automatically transmitted to the aircraft and displayed to the pilot. The additional ATC computer equipment required to provide this service is relatively modest. No controllers would be required. IPC need only be applied when a collision is possible; otherwise, all aircraft would follow normal procedures.

IPC requires aircraft in the airspace served to be equipped with a simple ground-to-air data link and display in addition to the beacon transponder. In the upgraded Third Generation System, this IPC data link and display should be a low cost integral part of the beacon transponder.

IPC appears applicable to traffic densities as high as that predicted for the Los Angeles Basis in 1995. Even there, assuming completely random flight, IPC is estimated to require only five commands per hour per VFR aircraft. At intermediate densities, only aircraft wishing separation service need have data link (although all must be transponder equipped). While substantial amounts of ground computations would be required for IPC, the increasing power and decreasing costs of computers will make IPC quite practical in the late 1970s and beyond. In some portions of the airspace, the information and instrumentation needed for IPC could be used to mark the boundaries of uncontrolled air routes ("VFR Highways"). The additional order such routes provide is likely to permit high density flights without the collision risk that would otherwise be expected at such densities.

While the Committee recognizes that requiring all users of the denser portions of Mixed Airspace to be transponder equipped will be burdensome to some, it sees no feasible alternative if aviation growth is to be accommodated at acceptable levels of safety. The service provided will more than justify the cost.

Automation

A third problem relates to limitations in the control process due to (1) the potential scarcity of controllers, and (2) saturation of manual control at major hubs.

There are now about 16,000 highly skilled controllers, excluding supervisors, employed by the FAA. The 1968 controller labor cost was $0.25 billion. The number of controllers required increases at least directly with the traffic. Despite the limited automation of the Third Generation system presently being implemented (NAS Stage A[7] and ARTS III), the FAA estimates that more than 33,000 controllers will be needed by 1980, and costs will rise at least in proportion. It may be extremely difficult to maintain such a work force and, even if possible, costs may rise sufficiently to jeopardize public acceptance.

The problem of saturation of the manual control process is especially serious in the transitional airspace between en route and terminal regions. In New York,

[5] "Mixed Airspace" has come to be used by the Committee to denote airspace shared by controlled and uncontrolled aircraft.
[6] Pilot Warning Instrument and Collision Avoidance System.
[7] National Airspace System and Automatic Radar Control Terminal System are descriptive of the automation being implemented in the present Third Generation System. See Appendix B.

certain of these sectors are already operating at saturation. While it is possible to alleviate this problem somewhat by rerouting and resectorization, New York, and possibly other hubs, will be in serious difficulty before 1980 without more automation.

The Committee studied the effects of increased automation in the New York terminal area; it believes the results can be extrapolated to other regions. One conclusion was that, by expanding the semi-automation of NAS Stage A and ARTS III to include spacing, sequencing, and conflict prediction and resolution, and by adding data link, two to three times the present traffic could probably be handled by the same controller work force. The introduction of automatic IPC to assure separation may prove sufficiently successful and reliable that controller efficiency may be increased even further. Resectorization and non-direct routing, taking into account a widespread area navigation capability, may unload the busiest sectors so as to increase capacity by an additional factor of two to three, but with a proportionate increase in the number of controllers.

By these means, the control function of the upgraded Third Generation System can be made to handle the traffic projected for the 1990s. Should higher levels of automation prove feasible, it would be possible to handle the traffic of the 1990s with fewer controllers.

Data acquisition/data link

The current data acquisition system is working effectively and receiving wider user acceptance. Difficulties experienced during its implementation are being overcome. However, to provide the accuracy and speed of response required for monitoring close spaced approaches and the interference free capacity that will be needed when all aircraft in dense airspace are transponder equipped, substantial modifications will be needed.

Data link is clearly a requirement. Air-to-ground communications for the Third Generation ATC system under present plans is limited to VHF voice. While ATCRBS automatic identity and altitude reporting will unload the controller somewhat, FAA studies indicate that controllers' communications workload may seriously limit the increased efficiency available from automation. Furthermore, an automatic separation assurance function, such as IPC, requires at least a ground-air data link.

The Committee believes that the ATCRBS system should be upgraded by (1) providing for the use of phased array interrogator antennas in the denser hubs to achieve enhanced accuracy and data rate, and by (2) including an additional "discrete address" mode[8] to increase capacity in the denser regions. The addition of this mode would permit the simple addition of two-way ATC data link service with ample capacity for the traffic forecast for 1995. Thus, upgraded ATCRBS could provide a common data acquisition/data link system which would operate nationally on a single channel.

The Committee has conducted preliminary system design studies and finds a number of ways to perform this upgrading which differ in the degree to which they modify the present system. All of these approaches, however, are compatible with continued use of the transponder equipment presently being produced. Comprehensive system engineering is required to specify the upgrading program in detail.

Many members of the aviation community believe ATCRBS should be upgraded along these lines. There are others who believe that a new system using multilateration should be introduced in parallel with ATCRBS and should then gradually supplant it.

The Committee has compared these approaches and unanimously agrees that the ATCRBS should be upgraded rather than replaced. This conclusion is based on studies of (1) feasibility and cost of incrementally and compatibly upgrading the ATCRBS, and (2) technical risks[9] and incompatibility of the various multilateration systems.

Navigation and landing aids

The VORTAC navigation system, while less accurate and more wasteful of bandwidth than modern technology could provide, can be compatibly and incrementally upgraded so that it will present no impediment to the growth of aviation before the 1990s.

[8] Only designated aircraft are interrogated.
[9] Primarily multipaths and siting problems.

It is possible to navigate routes separated by two miles near busy terminals utilizing VOR/DME, area navigators and modern flight directors assuming monitoring by the upgraded ATCRBS.

A navigation feature is available in the data link/data acquisition system. Because the location of all equipped aircraft is known continually to the ground computer, position information can be made available to the pilot on request via the data up-link. The navigation accuracy would be better than ½ mile anywhere in the service area. It is not suggested that navigation information derived in this matter substitute or replace the basic VORTAC system. It should prove useful, however, for updating a dead reckoning system or confirming and/or refining any other air-derived position information.

The Committee recommends rapid implementation of the scanning beam microwave ILS. It provides (1) increased accuracy and reliability due to freedom from site and overflight effects, and (2) guidance information for curved approaches and variable glide slopes, all leading to increased capacity at minimum noise levels.

Back-up systems

The lives of tens of thousands of people may depend on the continuity of operation of the ATC system. The inherent reliability, redundancy, and recovery modes from failure must be designed with extreme care.

The ATC equipment must be designed so that massive ground failure is extremely unlikely. The equipment must be inherently reliable and be designed to withstand external failures, such as power loss, lightning, etc. It must be engineered for sophisticated preventive maintenance. It must be installed, operated, maintained, and frequently tested so as to ensure that the design reliability is achieved.

The ATC system must be able to recover from (1) failure of portions of the ground environment, (2) failure of airborne equipment, and (3) an aircraft's deviation from its prescribed flight path. The design of these recovery modes becomes more demanding as traffic density increases. Multiple coverage should be the prime recovery mode to ground failure, i.e., each center should be backed up by neighboring centers and major terminals within the center; critical data acquisition sites should be covered by neighboring sites; terminals would be backed up by the center.

Emergency procedures for safe recovery from failure should be an integral part of the original system design. Recovery actions in which both pilot and controller must participate should be well understood and frequently simulated by all participants. The procedures for such rare failures need not be at all expeditious nor need they be as safe as measures that would be used normally.

The Committee considered the need for mandatory autonomous back-up airborne equipment, such as stationkeepers. It is inclined to the belief that overall ground system reliability plus emergency recovery procedures will be sufficiently effective to render such equipment of doubtful value. This, however, only reflects the Committee's judgment since no comprehensive study of the relationships between system design and recovery modes is available.

Radar skin tracking is now assuming a back-up, rather than primary, role as the implementation of ATCRBS proceeds. In this role, it backs up the ground interrogator as well as providing skin tracks on aircraft without operable beacons.

Radar is still extremely useful in NAS and ARTS tracking functions when ATCRBS data is missing due to aircraft shielding or poor data reliability due to over-interrogation, garbling, or fruit.

Even though ATCRBS reliability is improving, until such time as multiple antennas are installed on larger aircraft, transponder replies will fail routinely on certain departure and approach routes, and automation progams will use radar data in this portion of the airspace.

As traffic density increases, the cost of correlating radar data and ATCRBS data to find the unequipped intruder or failed equipment becomes substantial, and perhaps more than the cost of transponders on all aircraft that would not otherwise require them. Wider implementation and increased reliability of transponders will reduce the threat of the unequipped intruder and, in time, render a primary radar system unnecessary for air traffic control, although its use for air defense and weather data may continue.

There is a procedural response to airborne equipment failure. Back-up procedures using radio communications and VORTAC can be initiated with the aircraft whose transponder or data link has failed.

The Committee endorses steps being taken to encourage widespread adoption of the transponder. The FAA should also consider the possibility of requiring transponders as initial equipment on all new aircraft. Larger aircraft should carry multiple beacon antennas to assure reliability of the data acquisition system during turns and climb/descent maneuvers.

The air derived collision avoidance system (CAS) has been suggested as a means for protecting against an aircraft which has deviated from its prescribed flight path, either because of an aircraft failure or an ATC system failure. While such might prove satisfactory for isolated or momentary failures, the CAS has never been proposed as a substitute for the ground based ATC system.

For CAS to serve its intended purpose in an isolated or momentary failure, it is important that the CAS alarm region be less than the ATC separation being employed, otherwise its false alarm rate and interaction on ATC would be unacceptable. The separation employed by ATC is determined by the accuracy and data rate of the ATC data acquisition/data link, and the response time of the control and aircraft systems. There is some doubt that the CAS alarm region can be made sufficiently small for all airspace in a system based only on range and range rate information. This will become more critical as traffic density increases and as ATC separation standards are decreased. The exchange of additional information in the CAS may help, but this complicates the equipment further and would add to its cost, thus limiting the possibility of widespread adoption. Without broad implementation, there is little utility to CAS. In spite of this limitation, the Committee recognizes that some airlines may elect to implement CAS. The FAA should study CAS performance to determine to what extent it may be a useful supplement to the ATC system.

The recommended upgraded third generation system

In summary, the recommended upgraded Third Generation System includes: scanning beam microwave ILS for landing and terminal navigation: airports that are designed for high capacity; improved VOR/DME for en route and terminal navigation with wide implementation of area navigation; a discrete addressed ATCRBS that incorporates an integral data link (of varying sophistication, depending on the aircraft) and that employs phased array ground interrogators; automatic intermittent Positive Control, at least in the denser positions of Mixed Airspace, to safely handle increased traffic while maintaining freedom of flight; an increased capability of NAS/ARTS as far up the automation ladder as becomes possible; and a coupling of the control function to aircraft via data link.

PLANNING FOR THE FUTURE

Fourth generation system

While the upgraded Third Generation System appears able to handle the traffic estimated into the 1990s, it is likely to exhibit significant deficiencies before the end of the century; specifically:

The semi-automatic control process may be near saturation at major hubs, and non-direct routing may be required at peak hours to achieve capacity.

The controller population, in spite of the added efficiency provided by a fully implemented NAS/ARTS, may have grown to 35,000 or more.

Route separation requirements, especially in transitional airspace, imposed by navigation errors may force additional non-economic routing and may contribute to control system saturation.

Accuracy and coverage of navigation and surveillance may be inadequate to meet V/STOL air carrier needs and also inadequate to meet both general aviation and the air carriers' needs in remote areas.

The improved DME system may be at the limit of its capacity.

While ad hoc fixes could be used to overcome some of these deficiencies, the Committee feels a Fourth Generation System should be in orderly development which can supplant the upgraded Third Generation System.

Possible components of a Fourth Generation System were studied using twice the demand forecast for 1995. The total U.S. fleet was assumed to consist of one million aircraft, with a peak instantaneous airborne count of 100,000. This fleet was almost all general aviation aircraft, but the one percent which is air carrier made ten percent of the flights and generated eighty to ninety percent of the passenger-and-crew miles.

Universal coverage, improved system accuracy, and much higher levels of automation, if feasible at reasonable cost, could overcome the long-term pro-

jected deficiencies of the upgraded Third Generation System. The Committee's review of future possibilities identified space and computer technology as offering the greatest potential advantages.

A more automatic ATC system

To obtain an understanding of the feasibility and cost of proceeding towards a greater degree of automatic ATC operation, a study was made of the Los Angeles Basin under the design conditions for the Fourth Generation System. The en route area (approximately 400 x 800 miles) was assumed to have an instantaneous airborne count of 8000. Of these, 4200 were in the terminal area, a region 60 x 120 miles in area by 10,000 feet in altitude. Within this region were 12 high density terminals. The study was limited in that it did not address the problems of the highly sophisticated logic that would be required for full automation, or the difficult software problems involved. It did, however, assess in detail the computer requirements for all of the calculations that would be required once a specific control strategy had been selected. The conclusion was that the computer technology of 1975 will be adequate to cope with twice the projected 1995 traffic. The computer costs for automation of the Los Angeles Basin, both terminal and en route, for the traffic defined above were surprisingly low—less than $50 million.

Adding the functions of conflict prediction and resolution, spacing, sequencing, and metering with ground-air-ground data link to the semi-automatic NAS Stage A and ARTS III automates all normal ATC functions. But this is not the limit to automation possibilities. A higher level of automation would have the controller provide system status inputs such as weather and wind shifts, blocked runways, aircraft emergencies, ATC equipment failures, and the ATC system automatically accommodates to these inputs in directing traffic. Such a higher level of automation requires a system design and reliability (both software and hardware) such that no emergency develops that cannot be resolved by the man-machine combination. In such a system, man is the manager and exercises strategic control of the system. Whether the upgraded Third Generation System could be used in this manner can only be answered after accomplishing the recommended research and development program.

The initial studies of automatic Intermittent Positive Control for Mixed Airspace seem sufficiently promising that applications of IPC to those positive control sectors where merging and sequencing are infrequent should be thoroughly tested.

In addition, the Committee recommends the prompt initiation of a system study that determines whether the higher levels of automation achieved by the incremental additions to NAS/ARTS would be fundamentally different from an automation program that was derived from basic considerations of air traffic flow capacity and safety.

In summary, the Committee recommends three parallel approaches toward higher levels of automation—incremental, but rapid, additions to the NAS/ARTS program for positive control and dense terminal airspace; IPC for Mixed Airspace and possibly some positive control regions; and fundamental studies of higher levels of automation.

Satellite systems

Three-dimensional position accuracy of a hundred feet and universal coverage appear attainable from a properly designed satellite system. Because of relatively high elevation angle, satellites can have less multipath involvement than any ground based sensors.

The airborne component of such a system might be comparable in cost to present transponders if all computations were performed on the ground and relayed via satellite to the users, and the satellites employed high power and highly directive antennas.

A satellite based system might contribute to solving such perennial aviation problems as low altitude navigation and surveillance for V/STOL aircraft, separation assurance for air carriers engaged in infrequent services to low density regions, the need for approach aids at remote airports.[10]

The Committee considered one such system employing a constellation of five synchronous satellites designed to serve all the CONUS airspace, provide up to

[10] In addition to aviation, there will be a wide range of users for a precision navigation-surveillance-data system which does not suffer the usual line-of-sight restrictions. Marine search and rescue, police and fire, and many military users could be compatibly served at data rates which would add little additional to the aviation load.

100,000 instantaneous participating aircraft precision navigation (including altitude), data acquisition, and ATC data link services. The annual cost for the satellites and associated ground equipment appears to be less than $100 million.

The major technical and operational problems relate to (1) the development of a signal processing system adequate for the traffic within a reasonable bandwidth, and (2) achieving the reliability demanded of a system that is concentrated as compared to the current diffuse system, especially immunity from failing catastrophically due to hostile human acts. The Committee recommends a research program relating to these problems.

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5. Recommended Development Program

The FAA's problem is similar to that of a public utility—a steady, fairly predictable growth in demand requiring a continuing growth in services with an accompanying growth in technology. An appropriate response to this situation involves both long range planning and a continuing R&D program to prepare for future needs. The Committee has been hampered in its efforts by a lack of an adequate R&D and data base on which to predicate its recommendations. This is related to a long history of austere R&D budgets for air traffic control. The Committee is convinced that a policy of low R&D expenditures is not economical, but is, in the long run, very expensive, especially in an area of high and rapidly advancing technology such as air traffic control. In addition to the major R&D investment needed in the near future to cope with the present problem, the Committee recommends a general policy of increased R&D effort for air traffic control. However, to be effective, this effort must be closely coupled to overall system planning and system engineering. System engineering, in turn, requires an intimate knowledge of current operating problems.

The research and development recommendations are categorized into three major groups:

1. Increase airport capacity to satisfy the demands in the 1975–1980 period and beyond.
2. Provide en route and terminal airspace capacity adequate for the traffic of the 1980s.
3. Determine the ingredients of a Fourth Generation ATC System for the post 1990 period.

Program 1 objective.—Increase Airport Capacity.

1.1 Perform major urban airport system studies dealing with capacity increase and noise reduction possible through (a) dual lane runways; (b) close spaced parallel runways; (c) curved approaches based on scanning beam microwave ILS; (d) two-step glide slope; (e) power cutback during climb; (f) retrofit of the 4-engine jet fleet with quiet nacelles; and (g) addition of terminal automation capability of the ARTS III program, such as command control sequencing and data link formatting. Estimated duration, 2 years; estimated cost, $4 million.

1.2 Develop, test, and evaluate a wide angle scanning beam microwave ILS for the high density terminal as well as a simplified microwave ILS for the low density or general aviation airport. Develop the airborne course computers to operate with the scanning beam microwave ILS so as to perform system tests. Evaluate feasibility of transmitting aircraft cross track position to the ground. Estimated duration, 3 years; estimated cost, $10 million.

1.3 Conduct flight tests to (1) verify the safety of closed spaced parallels and curved approaches, utilizing guidance derived from the scanning beam microwave ILS, and (2) prove the safety of nominal time separation and reduced longitudinal separations utilizing the recommended data acquisition system as a monitor. Estimated duration, 3 years; estimated cost, $8 million.

1.4 Develop procedures for evaluating the wake turbulence hazard and measuring vortex locations and intensity and for providing this information to ATC. Test the vortex suction technique for clearing runways of wake turbulence. Conduct exploratory work including vortex decay by blowing. Estimated duration, 3 years; estimated cost: $5 million.

1.5 Develop systems for detection and control of aircraft and vehicles on the airport surface. Estimated duration, 3 years; estimated cost, $10 million.

Program 2 objective.—Increase the En Route and Terminal Airspace Capacity of the Third Generation Air Traffic Control System to Accommodate Traffic up to the 1980's.

2.1 Conduct a system integration study of the upgraded Third Generation air traffic control system.

(a) Integrate the upgraded ATCRBS, including its data link and computation facilities with the upgraded NAS and ARTS systems.

(b) Develop an upgraded ATCRBS implementation plan with and without a frequency change from 1030–1090 to 1560–1575. Study the feasibility of operating components of the current ATCRBS at 1560–1575, as well as incorporating a data link.

(c) Define the services that should be provided in Mixed Airspace when aircraft are equipped with the upgraded ATCRBS. Where are "VFR Highways" appropriate, what is required to enter and navigate them, where is IPC service appropriate, how does the mix of upgraded ATCRBS and standard ATCRBS beacon affect the quality of IPC? Develop and evaluate IPC conflict detection and resolution software for various traffic densities and distributions. Develop and evaluate "VFR Highway" concepts and the required software for various traffic densities and distribution.

(d) Define the services that should be provided in Positive Controlled Airspace when the ATC data link beacons are part of the upgraded ATCRBS. How are clearances requested, provided, and verified? How are ATC commands in the en route and terminal airspace provided and acknowledged? How are ATC warnings and missed approach directives provided? How do these services reflect in the system design?

(e) Develop a comprehensive reliability plan for the Third Generation System, including the ATCRBS, ARTS, NAS, towers, landing and navigation aids, radar surveillance, and communication systems. The recovery modes from failure of any of the components of the system or its interconnections should be carefully developed. Simulation of these recovery modes should be conducted with great care, and personnel should be rehearsed in their execution. A comprehensive plan for increasing the inherent reliability, for providing sophisticated preventive maintenance, and for improving the reliability of the present system should result from this study. Another result should be the specification of the inherent reliability, redundancy, and recovery modes of the upgraded Third Generation System. This should be verified by real time simulations. Specifications should be prepared for all parts of the system as a result of these tests. If these tests indicate an independent, air derived back-up mode is required, specifications should be prepared and its integration with the ground environment should be specified. Estimated duration, 3 years; estimated cost, $25 million.

2.2 Modify the ATCRBS to provide increased surveillance accuracy and to achieve better reliability by adding a discrete address mode data link function. The ground based interrogator in a high density terminal should be a phased array with substantial horizontal and vertical aperture. The interrogator for the small terminal should be developed. The sophisticated airborne component should be capable of (1) 100–200 foot range accuracy, and (2) initiation, receipt, and verification of flight clearances. The general aviation airborne component should be capable of verification and acknowledgment of IPC commands and initiation, receipt, and verification of "VFR Highway" information should the system study indicate this mode to be desirable. Develop a reliable, low cost altitude encoder. Estimated duration, 3 years, but requires priority; estimated cost, $40 million.

2.3 Develop the full center automation (NAS) program, including conflict detection and resolution, flow control sequencing and metering, and those portions of IPC and ATC data link assigned to the centers as a result of 2.1. Provide experimental facilities for simulation and live testing. Estimated duration, 3 years; estimated cost, $30 million.

2.4 Develop the full ARTS program, including command control sequencing, threat evaluation of deviation from parallel courses, intruder detection and resolution, and those IPC and ATC data link functions assigned to ARTS as a result of 2.1. Provide experimental facilities for simulation and live testing. Estimated duration, 3 years; estimated cost, $30 million.

2.5 Institute an adequate research program in the techniques and data collection area to assure a more complete data base for future development in various areas. This would include research into multipath, coding, and synchronous techniques, improvement of communication system reliability, and review of satellite system technology for over ocean surveillance and communication. Estimated duration, 3 years; estimated cost, $15 million.

Program 3 objective.—Test the Feasibility of Major Innovations in the Air Traffic Control System that Might be Key Ingredients of a Fourth Generation System.

3.1 Studies on automating the ATC system. Is it possible to achieve the reliability in software and hardware necessary when the ATC decision process is mechanized? What is the man-machine relationship as automation proceeds well beyond the NAS and ARTS level? Will an automation approach based on fundamental air traffic flow, capacity, and safety consideration be different and better than incremently increasing the automation capability of NAS/ARTS? Estimated duration, 5 years; estimated cost, $15 million.

3.2 Conduct system studies on the use of a cluster of synchronous satellites as a base for data acquisition, navigation, communication system for aircraft in the continental United States. Study a signal processing system adequate to service all instantaneous airborne aircraft in the post 1990 period. Study the vulnerability of a satellite system, including its ground complex. These problems and others should be part of this study to determine the feasibility, economics, and desirability of a system employing satellites as a data base for an air traffic system in the period beyond 1990. Estimated duration, 3 years; estimated cost, $10 million.

The recommended research and development effort is not exhaustive, it treats only items of highest priority. Some of the programs are included in FAA plans or are based on previous FAA efforts. Some are not. All are organized to provide the basis for achieving a given system objective (in safety, efficiency, or capacity) by a certain time. The recommended funding levels are estimated to complete the R. & D. in advance of the predicted requirements.

TABLE 5-1.—RECOMMENDED DEVELOPMENT PROGRAM CONTRACT COSTS

Program	Cost (in millions)	Duration (in years)
1. Increase airport capacity:		
1.1 Urban airport retrofit studies	$4	2
1.2 Microwave ILS development	10	3
1.3 Flight tests of reduced separation	8	3
1.4 Wake turbulence studies	5	3
1.5 Airport surface traffic control	10	3
Total	37	
2. Increase airspace capacity:		
2.1 System integration study	25	3
2.2 Develop discrete address ATCRBS	40	3
2.3 NAS automation extension	30	3
2.4 ARTS automation extension	30	3
2.5 Technique developments	15	3
Total	140	
3. 4th-generation system:		
3.1 Studies toward higher automation	15	5
3.2 Satellite system studies	10	3
Total	25	
Grand total	202	

Mr. HECHLER. What is your projection of how long it will take for the review to be completed?

Secretary BEGGS. It is going to take some time to convert the report into a meaningful long-range plan. The reason is that there are a number of factors that have to be taken into consideration to relate the Alexander recommendations to the existing program the FAA has.

In addition, we have the problem—our intent is to expand the air traffic control R. & D. program quite substantially. As a matter of fact, our projection is that with the passage, or assuming the passage of the Airports Airways Expansion Act, we will more than double the program and perhaps in real terms probably quadruple the program because a major part of that R. & D. money has gone into areas that are not strictly R. & D. on the air traffic control system.

So what I am saying is that we are right now wrestling with the problem of laying out the long-range R. & D. program in this expanding program, and we have to relate the Alexander recommendations to those plans, to take advantage of what the Alexander committee developed in laying down a plan that carries into the 1970's. Because that is what he is really talking about, he is talking about 10 years out. And having had some experience in planning research and development efforts, planning for 10 years is not easy.

It is a difficult process and you have to make projections as to where you think you can go, based on the technology of today, and then you have to make projections as to where you think you will be able to go based on extrapolation of those technologies.

So I would say that hopefully we will have some handle on our FAA R. & D. program, the R. & D. program that we have in the Office of the Secretary, and the Alexander report, prior to the passage of the 1971 budget. In other words, I think we will be able to grind these things into the 1972 budget cycle.

Mr. HECHLER. I hope you will keep this committee very closely posted on the progress of this review and when it will be completed.

Secretary BEGGS. Yes, sir.

Mr. HECHLER. You have been an official in NASA and now that you are in DOT how do you view in a different way any difference in the role of NASA in its aeronautical R. & D.? Have you changed the relationship any or do you have any fresh ideas as to how NASA ought to proceed on its aeronautical R. & D. in the future?

Secretary BEGGS. I haven't really changed any of my opinions on the role that the two agencies should play. It has always been my view that the proper role of DOT–FAA in this process is to try to formulate objectives and to try to outline problem or problem areas in such a way that NASA can respond by working them into their research program. I think there probably is a great deal more that we can do in expanding the communications between the two agencies. As an example of an improvement in the communications process, we will be investigating and discussing a great deal how we can take advantage of the NASA research centers in much the same way, or along the same lines, that the Army has been using Ames.

There also is I think a great necessity to expand the dialogue. There has been, I think, kind of an inhibition to crossing certain lines. Particularly when you get into the air traffic control area, there has been a feeling on the part of some of the people in the Department that there are certain Department prerogatives and certain NASA prerogatives, and you shouldn't cross the line.

I think we can do quite a bit towards looking at the thing more as a system and getting both DOT people and NASA people to work together from the point of view of the whole air system, as opposed to "You do aeronautics," and "You do air traffic control," and the twain will meet only after we have completed the research.

Mr. HECHLER. I know exactly what you are talking about. As I commented earlier to Mr. Pelly and Mr. Wydler, we face the same problem here in Congress, of the inhibition in crossing committee lines, when you have a problem that really ought to be looked at as one large problem.

How will the probability of the passage of the airport airways bill affect NASA's aeronautical research in the future?

Secretary BEGGS. Well, it will not directly, although as I said, we are exploring ways to make use of the NASA research capability.

Mr. HECHLER. I mean particularly that bill in itself, since it puts so much emphasis on planning, to stimulate the development of more planning and research within FAA and DOT. Won't it have a comparable effect on NASA's operations?

Secretary BEGGS. We would hope so. We would hope that by the exchange of personnel and perhaps by actually working in some of the NASA research centers we could not only help ourselves by stimulating some of the plans and research processes in the Department of Transportation but perhaps stimulate further efforts of NASA.

It has always been my view that the program in NASA was in general a pretty well configured program. It is thin in certain areas, I believe, and I think there is room for expansion of several of the areas. I would like to see NASA do more in some areas.

When I was over there, recognizing the budget constraints that we were under, we tailored the program in the best way we knew how, and I think it was a good program, and I still think it is a good program. As a general rule they are covering all the necessary areas, but as I said before, I think it is thin in some areas.

I would like to see it expanded. I think from the point of view of that expansion, a greater interchange between us will stimulate that.

Mr. HECHLER. Specifically, we have been putting a lot of emphasis in this committee on some more work on V/STOL and STOL development. Now have you tried to set any more specific goals on the speeding up of this type of research by NASA toward the time when we can really utilize demonstration vehicles?

Secretary BEGGS. Mr. Chairman, I think we in DOT have to get our own house in order here before we push NASA too much in this direction. We are trying and have been trying to get a demonstration going, and to lay some plans so we can move out to demonstrate what can be achieved by the use of V/STOL aircraft.

We have talked to NASA in this area and I would think that further efforts in this area are justified on their part, but I think we have to decide clearly in DOT how far we are going to go in the demonstration area before we can move forward quickly in requesting more help from NASA. We haven't done that yet. That is regretful, but we haven't.

Mr. HECHLER. If you speed this up a little bit, would this help you overcome some of the airline resistance to the utilization of STOL say in the northeastern corridor?

Secretary BEGGS. Well, it might, although I should point out that this is not all a one-sided view. STOL aircraft right now are expensive to operate. There are some aspects of their operation that are not very well defined in terms of safety in their operation within the system.

They have some marginal capability under poor conditions, poor flying conditions, that give the airlines some concern and indeed give us quite a bit of concern. On the other hand, they do offer the potential of lending some hope of solving this system problem of tremendous congestion at the large jet ports, and really about the only way you can take that pressure off in a short-range time frame is to use something like V/STOL at landing strips that get away from the jet ports.

So they are potentially of great interest to us, but they do have some drawbacks. I think you have to look at both sides of the coin when you start to put pressure on the airlines to use the aircraft. My personal view is that the answer here is to get a demonstration started and to start flying aircraft in actual service and find out what we can do with them. This has always been the way the system has developed. It has been someone who takes the bull by the horns, gets something going, and finds out how he can use it within the system who generally proves out whether you can use it or not.

I think that is the key in this area. And we are trying to do that. It has been a slow and tough process, but we are trying to do this, and the FAA is pushing hard to get a demonstration going.

Mr. Hechler. I congratulate you on the statement you have just made, which objectively weighs just what the STOL can do. I wonder whether DOT has given any thought to developing a policy on STOL, for example, that can weigh the very things that you have mentioned and project into the future just where this airplane ought to relate to our entire transportation system?

Secretary Beggs. We had Mr. Secor Browne giving a lot of thought to this when he was our Assistant Secretary for Research and Technology. He unfortunately ran away from us and went over to the CAB, where I hope he is still thinking about it. The work that he was doing in this area is temporarily in abeyance while we get ourselves another Assistant Secretary for that area, and I hope we will have one within the next couple of weeks.

I am going to put him on this particular subject right away because I think it is an area that needs to be pursued right now.

Mr. Hechler. I made the observation at yesterday's hearings that I thought it would be extremely useful for the Nation to have a national aviation policy formulated, to look at the entire picture and set forth our goals and areas we ought to emphasize and work toward in the future. And I think it is just one little piece of that.

Secretary Beggs. Yes, sir. We fully concur in that. We found it is not an easy process to formulate national policy. You know the President early this year set us about trying to formulate an entire policy on transportation for the Nation, and we have been wrestling with that one for about a year, and we found it is not as easy as it sounds when you first set out to do it.

But we do feel that in a similar way a national policy on aeronautics and civil air transport must be developed. And the thing that we set Mr. Larry Greene out on in this civil aviation study was to come up with the basic papers and to study the areas that related to the national policy in aeronautics, which should enable us at the time that study gets downstream, somewhere within about a year or so, to start to grapple with the question of how one puts a policy like this together.

People have tried their hand at formulating national policy on transportation in the past. I have read a number of those studies, starting with the Weeks report that goes back 20 years or so, and while they did very well in what they were setting out to do in outlining the problems, the formulation of policy didn't quite come out as well. From the Weeks report through the studies that were done in the latter stages of the Eisenhower administration and President

Kennedy's report in the early 1960's, until the current time we still haven't quite come up with what we need. But we are going to try.

Mr. HECHLER. Mr. Helstoski.

Mr. HELSTOSKI. One question. You made reference, Mr. Beggs, to a study that was conducted in regard to public travel patterns toward airports. Is this some scientific study that was made by DOT? Is it available?

Secretary BEGGS. Yes, I believe it is available. I will dig it out and send it up to you. It is a study that was done several years ago. How scientific it is, I can't say. It was one of a number of econometric studies that have been done from time to time relating to travel in the corridors in metropolitan areas.

There have been a number of these econometric models constructed. The Northeast corridor study, which has gone on for something like 6 or 7 years, relates to the same kind of problem, that is, how do people move in highly concentrated corridors, in all modes of transportation. And you are able to draw some conclusions from these relative to the question that the chairman asked me, on which way—you know, how do you construct a system so as to truly serve the traveling public. Because you find in these things that people are moving in many, many different ways and they move by many, many different modes as they go from place to place.

One of the interesting things that comes out of some of the Northeast corridor studies, for example, and relates to the problem of V/STOL transport, is that the average speed of moving from Washington, D.C., to New York by almost any mode that you can think of in the high-density hours is about the same.

I mean you can drive there or you can drive down to the airport and take a plane, or you can get on a train, and you get there with about the same average speed, which is interesting to me.

Mr. HELSTOSKI. As a characterization, I said scientific. I wonder whether or not some of these studies were conducted by airport authorities?

Secretary BEGGS. Yes, they were.

Mr. HELSTOSKI. This was a portion of the total study. And I wanted to contrast it. Some of the study also included what I consider informal polling, while you sit in a plane as a passenger and answer several questions. Some of the polling that was done by airlines seems to me was totally improper because of some of the questions that were asked in conjunction with this so-called study that the airline was making, to make a determination of travel patterns of the public.

They were extraneous questions and it had nothing to do with it.

I had a second question, too. This is something that constituents ask quite often. Do we see any specific benefits that inure to the aviation industry as a consequence of our space program today, in terms of perhaps communications or something? I know we get the general answer that there is improvement in these areas.

What I am speaking of is in terms of a radical departure that could be employed to alleviate traffic congestion or perhaps noise abatement.

Secretary BEGGS. Well, there are a number of areas that have provided benefit, starting with the basic materials, work that was done in the program. This, of course, has been of benefit and is being applied right now to the aviation field.

The area that probably is of greatest interest currently is a satellite system for navigation and communications. I think we are within a matter of 2 or 3 years from having a satellite communications and navigation system serving at least the international flights. This will be, of course, a very material aid in accommodating the large increase in traffic we expect on all of the international runs.

There are any number of developments that have taken place in the Space Agency that have been applied in one way or another to the air traffic control system. Some of the display work that we are doing now, the displays for the air traffic control centers, draws on space technology. Much of the communications work does. And the fact that we are considering going up into L band communications in the future is probably a result of the fact that the technology resulting from the space effort and also work that DOD has done, has progressed to the point where we have confidence we can move into that band and have equipment which works and is economical.

Mr. HELSTOSKI. All right.

Thank you, Mr. Chairman.

Mr. WYDLER. Mr. Chairman.

Mr. HECHLER. Mr. Wydler.

Mr. WYDLER. A few additional questions.

Your statement on page 7, where you say you are expanding your research in noise abatement. What does that refer to specifically?

Secretary BEGGS. We are pursuing a number of areas——

Mr. WYDLER. I am worried about the expansion now. Is that in dollars, is that inflationary expansion, or is this real expansion?

Secretary BEGGS. No, we are trying to put some more dollars into—primarily this is directed to noise suppression. We have several contracts out to develop economical nacelles for the subsonic jets, which will with a relatively small weight penalty provide a substantial improvement in noise, in the order of five or six PNdB, perceived noise in decibels, upwards to a maximum of 15 PNdB, and we believe that we will be able in a matter of a year or two to have something that could be retrofitted to existing transports and also apply to new transports that will materially reduce the noise.

I think the major hope here——

Mr. WYDLER. What is the expansion? That is what I am interested in. You say you are expanding it. Now what are you doing that is expanding it?

Secretary BEGGS. We are putting more dollars into it, Mr. Wydler.

Mr. WYDLER. More dollars for the same thing?

Secretary BEGGS. Primarily the same thing; yes. I think, though, that the major hope here is in the new transports, like the 747, where from the beginning in the design of the transport the engine and airframe has been designed for a low noise output. That airplane will be some 10 or more PNdB quieter than the existing 707's.

Mr. WYDLER. Which they tell me——

Secretary BEGGS. Very significant.

Mr. WYDLER. Is one-half the noise.

Secretary BEGGS. That is right.

Mr. WYDLER. You can back that up?

Secretary BEGGS. Yes, sir.

Mr. WYDLER. Because I have a lot of people who question that, too, I want to tell you.

Secretary Beggs. Well, I hesitate—that comparison has been made and in the scientific sense it is true. But I hesitate to make it because if you stood beside a 747, it would still be pretty noisy, you know, but insofar as community noise is concerned, the noise that is perceived on the ground, it is very much quieter, one-half as noisy, and it is very striking, if you have heard it fly over.

Mr. Wydler. Well, Mr. Pelly has had that advantage. He tells me it is very quiet, but he didn't tell me how high that airplane was that was going over his house.

Mr. Pelly. They don't fly very high when they are going over my house, I can tell you that.

Secretary Beggs. They ran an experiment out at Boeing flying a 707 and a 747, and I can assure you that there is a very, very striking difference between the noise levels when each aircraft flies at the same altitude.

Mr. Wydler. This is what you are going to try to do with this expanded research on existing jets?

Secretary Beggs. That is correct, yes, sir, we are going to provide enough——

Mr. Wydler. The new noise levels for existing jets are going to take into account the fact that the airlines are going to have to quiet those engines down?

Secretary Beggs. We intend to do that.

Mr. Wydler. Now, just as an aside, this Tupelov—this Russian supersonic.

Secretary Beggs. Yes, sir.

Mr. Wydler. To me that looks just like the B–70. Is there any truth to that? I mean did they copy the B–70 or did they get one or what?

Secretary Beggs. Well, the Soviet designers are known to take the best from wherever they can get it. They have indeed borrowed from other designs many times in the past. The Tupelovs have a very interesting design institute. It is a father-and-son combination.

Frank Bormann, when he made his tour of the Soviet Union, visited the Tupelov Design Institute, and the two Tupelovs took him out to see the transport and he was very, very much impressed with the airplane. They took him all through it and sat him in the cockpit.

I saw him shortly after he returned, and he said it is a very, very fine machine. He was very much impressed with it.

Mr. Wydler. Finally, what would really happen—because people have suggested it to me—what would really happen economically, and what would happen to the economic arguments for that matter, if our country was simply to say that we weren't going to allow any of the supersonic jets to use Kennedy Airport? What would happen to the international market for these aircraft?

Secretary B[illegible]s. Well——

Mr. Wydler. Has anybody ever thought about that?

Secretary Beggs. For one thing, they would land in Canada, because the Canadians have welcomed them.

Mr. Wydler. I am sure they do. They could land in Siberia, too. But very few people want to go to Siberia or Canada. I asked, and the question is if a person wants to come to New York or the New York metropolitan area and he found out he couldn't get an aircraft to fly him there in this type, would he take the other type?

Secretary BEGGS. I wonder how he would take it if he found the Tupelov transport was flying into India and into Japan and across the Pacific into Australia and to all the other centers of commerce. Because it is my view if they were flying those routes, Americans going to those places would ride it. I just don't think that that is a good posture to take, that we close our eyes to this technology, which is what you are saying we are going to do, shut it out of the country and sort of close our eyes and pretend it isn't there.

To me it is an ostrich philosophy and it doesn't make the problem go away.

Mr. WYDLER. I am just trying to say this. To me somebody would answer the economic argument that the other countries are going to gain a great economic advantage by building these aircraft because they are going to be able to sell a lot of them to various countries besides themselves to use.

It seems to me with such a specialized aircraft, that there is only about three or four routes in the whole world that make it even close to being economically feasible to fly the aircraft, particularly if you are going to completely eliminate its use over land except at subsonic speeds, because then it loses all its advantages as a competitive plane.

So it would just seem to me that almost inevitably if you denied it at a few airports in the United States, the whole economic feasibility of that airplane would come crashing down. It would be a totally uneconomical aircraft. I am not suggesting we do that.

Secretary BEGGS. I understand.

Mr. WYDLER. But I am just thinking if anybody ever thought of what that might mean.

Secretary BEGGS. Many of the foreign airports are becoming very busy airports indeed. The studies that we made of our transport indicate that there is a potential on the transatlantic, transpacific routes for use of upward of 500 transports. Some of the studies that the English have done and have published indicate that there is a market for upward of 800 of these aircraft.

There are orders for the Concorde in hand right now of upward of 65. We have 122 commitments for our transport. We do not know whether the Soviets have sold any or not, but they are talking about several hundred of their aircraft flying the trade routes.

One of the interesting things to me about the supersonic is that it opens up markets that previously have not been as open to air transport on the subsonic jet basis. For example, the supersonic flying to South America will provide transportation that will get to the southern South American cities, which are the important cities to us, in about the same time as we now fly to Europe on the subsonic jets. And we know what a tremendous inducement that subsonic transportation was to travel to Europe.

I anticipate that this will open up South America to us on the same basis.

In addition, the Japanese economy, which is the fastest growing in the world and is now the third largest economy, will be within 7 to 8 hours transportation time away. I think that is very significant. When you start bringing countries that close together in time, the trade and the business development, the development of cultural relations, everything increases enormously, and this airplane, this machine will allow us to do what we have traditionally done with the Europeans.

Mr. WYDLER. Thank you, gentlemen.

Mr. HECHLER. Mr. Helstoski.

Mr. HELSTOSKI. I had one other question, Mr. Chairman.

Mr. Beggs, you made reference to navigational and air traffic control satellites, as possibilities of the future?

Secretary BEGGS. (Nods.)

Mr. HELSTOSKI. Has there been any resolution as to who would operate them? Would it be the private sector, or would it be governmental?

Secretary BEGGS. It is very probable that COMSAT would operate it and sell its services just as they sell their current communications services.

Mr. HELSTOSKI. Is this the thought, the present identification?

Secretary BEGGS. Yes, sir; the current planning is based on that.

Mr. HELSTOSKI. All right. Thank you.

Mr. HECHLER. Any other questions on my unbalanced left down here?

Mr. GOLDWATER. No.

Mr. HECHLER. I would like to ask two quick final questions.

I made the suggestion during yesterday's hearings that maybe it might be a good idea to give the Department of Transportation statutory membership on the National Aeronautics and Space Council. I am not asking you to put the stamp of any kind of official approval on that, but do you have any overwhelming objections?

Secretary BEGGS. No, sir. I have talked to Bill Anders about this several times, at his initiative. He has been up to see me after getting in down there. We have, of course, been observing——

Mr. HECHLER. Yes.

Secretary BEGGS (continuing). The activities of the Space Council for a number of years. So far as I know, we have never missed anything in those Council meetings, nor have we ever not been advised of anything that falls within our purview.

But certainly we would have, the Department would have no objection to sitting on the Council.

Mr. HECHLER. I noticed at the top of page 2 you said:

> We have had our first advisory committee and working group sessions.

What is this advisory committee, who heads it, and just what does it do?

Secretary BEGGS. Yes, sir. We asked Dr. Guy Stever to head a committee which would provide an overview of the work of this study group. Dr. Stever, as you know, has been very active in the study of aeronautics in general and air traffic control in particular.

He ran a committee study in the National Academy of Engineering about a year and a half ago, the results have been published, and we felt that he would be an ideal man to get into this. Some of the recommendations he made, or his committee made in the National Academy of Engineering report are a basis for some of the things we are doing in this civil aviation study.

So I think he is uniquely capable of providing an oversight of the entire study, and that is what we asked him to do.

Mr. HECHLER. Could you give the committee the membership of this advisory committee?

Secretary BEGGS. I can supply it for the record.

Mr. HECHLER. I mean for the record.

Secretary BEGGS. Yes, sir.

THE AD HOC STUDY ADVISORY COMMITTEE TO THE JOINT DOT/NASA CIVIL AVIATION R&D POLICY STUDY

The Study Advisory Committee will be established to provide the Chairman and Vice Chairman of the study with expert and broad advice and counsel in the conduct of the study. To insure the achievement of this end, the Committee will be formed utilizing the National Academy of Engineering and will be constituted with top level leaders in the air transportation field, from other Government agencies, industry, and universities. The Committee will meet periodically to review the status and progress of the over-all study activity and its many separate elements, and will advise the Management Committee of its views on these matters as well as content of the study. The Chairman of the Advisory Committee will serve on the Management Committee in an *ex-officio* capacity and thus will be kept in very close touch with the over-all study and its many elements. It is anticipated that the Committee will meet at approximate quarterly intervals. The business of the Committee will primarily be accomplished at the meeting. It may be desirable to have an extra meeting or so at the request of the sponsor. It may also be requested, on occasion, that members prepare a special working paper for the use of the Committee and the study. Finally, it is expected that the Study Advisory Committee may prepare, at the conclusion of the study, its own report of the findings, for presentation to the Secretary and Administrator.

PROPOSED MEMEBERSHIP

ASEB AD HOC STUDY ADVISORY COMMITTEE ON AERONAUTICS

(In support of DOT–NASA Study of Civil Aeronautical R&D Policy)

H. G. Stever (ASEB), President, Carnegie-Mellon University, *Committee Chairman.*

R. L. Bisplinghoff (ASEB), Dean School of Engineering, MIT.

W. L. Hawkins (ASEB), Vice President, Science and Engineering, Lockheed Aircraft Corporation.

W. C. Mentzer (ASEB), Senior Vice President, Engineering and Maintenance, United Air Lines.

P. W. Pratt (ASEB), Vice President and Chief Scientist, United Aircraft Corporation.

J. M. Kyle, Jr. (ASEB), Chief Engineer, The Port of New York Authority.

R. H. Miller (ASEB), Head, Department of Aeronautics and Astronautics, MIT.

G. E. Solomon (ASEB), Vice President and Director, Systems Laboratories, TRW Systems Group, TRW Inc.

S. L. Higginbottom, Executive Vice President, Eastern Air Lines.

J. E. Gallagher, President and Chief Executive Officer, New York Airways.

J. E. Knott, Plant Manager, Allison Division, General Motors Corporation.

J. M. Nissen, Manager, San Jose Municipal Airport.

H. E. Davis, Director, Institute of Transportation and Traffic Engineering, University of California.

G. B. Litchford, Consultant.

J. P. Mitchell, Vice President, Chase Manhattan Bank.

W. P. Lear, Sr., Chairman of the Board, Lear Motors Corporation.

J. E. Gorham, Vice President, SARC Inc.

S. Seltzer, Director, Air Traffic Control Research, American Airlines.

W. L. Pereira, President, William L. Pereira & Associates.

R. E. Hage, Vice President, Engineering, Douglas Aircraft Company.

E. J. Swearingen, President, Swearingen Aircraft.

Mr. HECHLER. How often do they meet?

Secretary BEGGS. Well, this has been the first meeting. We have been somewhat slow in getting them organized. We hope to bring them up to date in the order of every 3 months or so. Of course, committee members and Dr. Stever in particular will be kept advised on a continuing basis as we proceed.

Mr. HECHLER. It would be helpful if you just give us the membership of the committee and what their general charter is.

Secretary BEGGS. Yes, sir.

Mr. HECHLER. And what their future activities are likely to be. It will be very helpful for us.

Secretary BEGGS. I will do that.

Mr. HECHLER. Any further questions?

(No response.)

Mr. HECHLER. If not, thank you very much, Mr. Beggs.

Secretary BEGGS. Thank you, Mr. Chairman.

Mr. HECHLER. The committee stands adjourned until 10 a.m. tomorrow——

Mr. HINES. Thursday.

Mr. WYDLER. Not until Thursday.

Mr. HECHLER. Thursday at 10 a.m.

(Whereupon, at 11:50 a.m. the subcommittee adjourned, to reconvene at 10 a.m. on Thursday, December 4, 1969.)

AERONAUTICAL RESEARCH

THURSDAY, DECEMBER 4, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10:03 a.m., in room 2325, Rayburn House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The committee will be in order.

The hearings on aeronautical research and development will continue this morning with witnesses representing Aerospace Industries Association.

We will hear first from Mr. Kendall Perkins, corporate vice president, engineering and research, McDonnell Douglas Corp.

Good morning, Mr. Perkins.

Mr. PERKINS. Good morning.

Mr. HECHLER. Do you have an opening statement you care to present?

(A biographical sketch of Mr. Kendall Perkins follows:)

KENDALL PERKINS

Born: St. Louis, Mo., February 23, 1908.

Parents: Robert Fulton Perkins, Florence Gleason Perkins.

Academic: Washington University. B.S. in Electrical Engineering, 1928. D. Eng. (Hon.) Tri State College.

Married: Elizabeth Dorothy MacIvor, October 16, 1934.

Children: John MacIvor Perkins, August 2, 1935. Amy Doris Perkins Bethke, June 11, 1938.

Professional Activity: 1928-1940—Curtiss-Robertson Airplane Mfg. Co. After serving as a shop mechanic for six months was made foreman of the fuselage department. Transferred to Engineering Department in 1930 as Project Engineer handling engineering changes for a number of commercial airplanes including Curtiss Robin, Thrush and Kingbird and a series of Travelair biplanes. In 1936 became Project Engineer on design and engineering development of the CW-20 twin-engine transport (commercial prototype of Air Force C-46 Commando). This airplane saw cargo service throughout the world during the 1939-1945 war and is still in use here and abroad.

1940—American Airlines, New York. Research Engineer. Consultant to the Vice President of Engineering with relation to transport aircraft design requirements and other airline engineering problems.

1941—Office of Production Management. (Predecessor of the War Production Board), Washington, D.C. Head of Aircraft Scheduling Unit. Responsible for scheduling aircraft deliveries from all U.S. manufacturers as allocated to U.S. and allied users.

1941 to date—McDonnell Douglas Corporation. Joined McDonnell in November 1941 as Project Engineer in advanced design. Later assigned to engineering supervision on the XP-67 twin-engine fighter, then in the early design stage. Made Assistant Chief Engineer in October 1942.

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In January 1943, began work with the U.S. Navy in Washington on advanced design studies leading to the XFD-1, the Navy's first jet airplane. It served as the prototype for the FH-1 Phantom, the first complete airplane designed and produced by McDonnell. The success of this program led to a series of other jet fighters for the Navy and Air Force which represented most of the subsequent business of the McDonnell company.

Mr. Perkins was named Assistant to the Vice President for Engineering and Contracts at McDonnell in September 1948. Became Manager of Engineering in July 1949 and Engineering Vice President in April 1951 with functional responsibility for engineering work on aircraft, spacecraft and missiles.

Notable aircraft engineering work carried out at McDonnell included development of the F-2H Banshee and F-3H Demon series of carrier based fighters for the Navy, the F-101 Voodoo series fighters for three Commands of the Air Force, and a series of versatile F-4 Phantom II attack and fighter aircraft begun in 1954 and subsequently developed for the U.S. Navy, U.S. Air Force, Royal Navy, Royal Air Force and others.

The Mercury spacecraft carrying the first American in orbit was initiated and developed by McDonnell engineering, and the Gemini spacecraft carrying the first two Americans in orbit was later designed and developed.

A number of unmanned vehicles were initiated and developed at McDonnell, including the GAM-72 Quail decoy, the Model 122B Alpha Draco hypersonic missile and the Asset hypersonic test vehicle.

Subsequent to the merger of McDonnell and Douglas in April 1967, Mr. Perkins became Corporate Vice President, Engineering and Research of McDonnell Douglas Corporation, which produces a wide variety of aerospace systems including civil and military aircraft, spacecraft, missiles, and other products.

Home: 14 Kingsbury Place, St. Louis, Mo. 63112.

Office: McDonnell Douglas Corporation, P.O. Box 516, St. Louis, Mo. 63166.

Memberships: Fellow, American Institute of Aeronautics and Astronautics. Associate Fellow, American Astronautical Society. Director, St. Louis Research Council. Trustee, Washington University (St. Louis).

STATEMENT OF KENDALL PERKINS, CORPORATE VICE PRESIDENT, ENGINEERING AND RESEARCH, McDONNELL DOUGLAS CORP.

Mr. PERKINS. Yes, I do.

Mr. Chairman and members of the subcommittee, we greatly appreciate this opportunity to present the views of the aerospace industry regarding current and future R. & D. needed to keep the United States competitive with the rest of the world in aviation, and the role which NASA and the industry should play in providing such R. & D.

I am speaking in behalf of the Aerospace Industries Association which represents the principal U.S. manufacturers of aircraft, missiles and spacecraft, and their components. The aerospace industry is highly competitive and individualistic so that unanimity with respect to all of the questions at hand cannot be expected. We believe the ideas we are presenting today, however, represent general concurrence.

Mr. HECHLER. This committee certainly doesn't expect to get any kind of an overall official view that is agreed to by everyone. We are particularly interested in what you have to present now. If you have suggestions to make, we know you do not clear every one of them in advance.

Mr. PERKINS. We tried during the last few days to have enough dialog among ourselves that we could reach at least general concurrence on most of these subjects.

I will confine my remarks to R. & D. related to U.S. military and commercial aircraft except for VTOL and V/STOL aircraft. I understand these are to be covered by the following speaker.

Previous testimony before your subcommittee by people of many backgrounds and interests has brought out repeatedly the desirability of increasing the rate at which aeronautical R. & D. is carried out. These are value judgments and, while they are impossible to prove in a quantitative sense, we fully concur. All new aircraft, military and civil, spring from research, and this research is primarily the product of cooperative effort of the public and the private sectors; that is, NASA and the aerospace industry. I plan to describe this Government-industry relationship and the role of each, and to suggest areas where greater emphasis is needed. In doing so, I hope to convince you that two basic changes are required if we are to maintain leadership in aeronautics. First, NASA must have the necessary personnel and facilities to conduct an accelerated program of advanced aeronautical research. Second, the aerospace industry must be given more opportunities to develop and test actual hardware.

Before getting into detail, it might be helpful to discuss in a general way some of the rationale for initiating development of new military and commercial aircraft. With respect to military aircraft, the principal need is to see that U.S. aircraft are as good as or better than those of potential foreign opponents. A new model of a particular military type is only initiated when it becomes clear that it can provide an appreciable improvement in effectiveness as compared with the current model and when there is reason to expect that, without the new model, the United States might be at a disadvantage.

Because of long time intervals inherent in aircraft development this calls for a high degree of imaginative judgment and the ability to act on such judgment. The importance of making the correct and timely judgments is obvious and is accentuated by the shift from the old "mobilization" concept to a "force-in-being" concept wherein completely modern equipment must be maintained in our ready forces.

One of many factors in this judgment is assessment of the status of the technology of a potential enemy as this may affect the probability of his initiating development of new models. Another is assessment of the likelihood that the opposition will actually put new models into service by the time we can deploy our own. The time interval between a decision to develop and produce a new model military aircraft and realization of full operational capability may be from 5 to 10 years. It would be easier if we could be sure of the aircraft characteristics needed and the numbers required to assure future superiority over all potential threats. Experience repeatedly tells us that we can't look so far ahead unerringly. We have often had to proceed on the assumption that if the United States is technically capable of creating new aircraft appreciably superior to those now being used, other major countries can do the same and are likely to do so.

As long as the United States holds a clear technological lead over the opposition we can proceed under this assumption with reasonable deliberation and with reasonable safety.

In recent years, however, there is increasing evidence that we do not lead other countries as much as we once did. In some areas we may not lead at all. This reduces our margin of safety. How far we let this go is, of course, a matter of opinion.

Mr. HECHLER. Excuse me, may I interrupt at this point? I wonder if you will specify whether you feel this is due to our lack of

aeronautical research, or simply a catching up in the technological capability of other nations, or just exactly what factors do you ascribe this to?

Mr. PERKINS. I will discuss this a little later. I might point out now that my thesis here is it is a combination of a slowing down in aeronautical research, plus a slowing down in the rate at which hardware is built and tested in this country.

Mr. HECHLER. Yes. You may proceed.

Mr. PERKINS. One need look only at published photographs of foreign military aircraft which have flown in recent years to find that some of them incorporate features more advanced than those of our current production aircraft. Some of these features have yet to be used in flight hardware in this country. The British Harrier VTOL fighter and French Brequet 941 cross-shafted STOL transport have no counterparts in the United States. The Russian MIG-23 Foxbat fighter began setting unofficial world records for speed and altitude in 1965. (Officially recognized by the Fédération Aéronautique Internationale in 1967.)

Faced with the necessity of matching requirements and the long timespan for development, it seems obvious that more prototype starts have the potential of uncovering needed research areas and providing more options for full development as requirements become clearer.

This two-way interaction between aeronautical research on one hand and development of flying hardware by industry on the other begins with research such as we look to NASA for, such as concepts, techniques, and data. On the basis of such data contractors make design studies to bring out what can be practically done to meet future military requirements. The military services in turn have the difficult problem of matching expected needs with expected capabilities and, when the timing and other factors seem right, initiating the development of a new model and specifying its required characteristics. Competitors for the development contract must then pitch in and do their best to meet these requirements without committing to do things they can't be reasonably sure of doing. At this point they have often found in recent years, that there are gaps in the background data and the need to fill these gaps is urgent. To the extent that they have the time and the facilities they may undertake a crash research program themselves. This situation could be improved by expanding the leading edge of aeronautical research done by NASA.

Having each of several contractors doing some of his own research during a competition is not as wasteful as it may sound because to some extent each is proceeding along somewhat different paths and it is not known until later which will prove best. When no one knows the best answer, parallel competitive effort can be a virtue. Nevertheless, there is some duplication which should not be necessary. It would be more efficient and the results would be more reliable and comparable if more of the background research were available from NASA earlier.

I might interject that in two recent important fighter competitions the competing contractors all found themselves with a serious lack of background data of the type that NASA traditionally provides.

Mr. HECHLER. Excuse me, Mr. Perkins, could you expand on the observation you just made?

Mr. PERKINS. Yes. As bidders on both F-14 and F-15 competition in the last 2 years, we became vividly aware of the fact that, whereas

10 to 15 years ago we could turn to a number of NASA reports which would provide, for example, broadly based and systematically reported airfoil and wing configuration data—design criteria with which we could configure our airplanes—in these competitions much of such data was simply not available. Specifically, these airplanes require wings that are thinner than those reported in NASA data.

This is an area which NASA had not gotten into.

It is data we should have had on the shelf, and the people at NASA recognized we should have had it on the shelf but didn't.

Mr. HECHLER. In this particular case what is the timespan it would take to develop such data? In other words, how long ago would they have had to have started to come to the point where they would have the data immediately available you needed in this instance?

Mr. PERKINS. The timespans between initiation of test programs by NASA and the time the data is used can vary all the way from a minimum of 2 to 10 years or more.

Mr. HECHLER. In this particular case you don't have anything more specific?

Mr. PERKINS. I couldn't be more specific in this particular case. These programs run over periods of years, and it is hard to predict precisely when the data will be needed.

Mr. HECHLER. I hesitate to interrupt with a further question because you may be answering this in the rest of your testimony, but are you going to point out other areas where you feel NASA should start now in order to develop the data needed?

Mr. PERKINS. I expect to wind up my statement with just that.

Mr. HECHLER. Fine. You may continue.

Mr. PERKINS. There is also a chicken-and-egg relation between research and hardware development. There are a number of areas where the need for research is only disclosed by attempts to build flying hardware and by encountering the unforeseen problems which inevitably emerge during the course of developing, producing, and operating complex equipment in which the state of the art is being advanced. These problems have come to be called the unknown-unknowns and are the greatest source of technical risk in the aerospace business. They are also a major contributor to cost growth of aircraft development programs.

The number of new aircraft models sponsored by DOD in recent years has been reduced drastically as compared with previous periods in the United States and as compared currently with the U.S.S.R. This applies particularly to development test articles and experimental prototype aircraft programs. The result has been that while most of the foreseeable research requirements have been reasonably met there has been a real lag in the rate at which unpredictable problems have been brought to light and hence the rate at which research applied to such problems has been carried out. We feel that the only solution for this is for DOD to sponsor more programs in which testing of experimental hardware and research go hand in hand.

With respect to civil aircraft, the situation is different. New commercial transports, for example, are initiated when the manufacturers and airlines reach the conclusion that a new model will have sufficient economic advantage over current models, as a result of significant advances in performance, comfort and safety, to justify the high devel-

opment and startup costs. The introduction of new transport models is also influenced by such factors as market growth rate and size considerations. However, the ability of U.S. transports to successfully compete with foreign transports in the world market depends to a large degree on relative technical sophistication. The lead which the United States once held over the rest of the world seems to have been retained in the areas having little dependence on research, such as reliability and maintainability, but in areas depending more on research, such as aerodynamic and structural sophistication, our lead seems to have narrowed.

Chairman MILLER. Just a minute. Mr. Chairman.

Mr. HECHLER. Mr. Chairman.

Chairman MILLER. Could you specifically point out cases where this has taken place? I am speaking now of commercial aircraft, and not military aircraft, which are not in our jurisdiction and which we are not concerned with. Can you tell me in each case now, what country has taken over the lead?

Mr. PERKINS. I am not taking the position, Mr. Miller, that other countries are ahead of us in transport aircraft, they are not.

Chairman MILLER. That is what I thought.

Mr. PERKINS. I believe the long lead which we once held is less long than it once was.

Chairman MILLER. This is natural.

Mr. PERKINS. I am specifically referring to France and the U.S.S.R.

Chairman MILLER. It is natural they are going to try to catch up. They have the basis of knowledge we used in making these developments.

Mr. PERKINS. Right.

Chairman MILLER. You can't hide this under a bushel, and they do go ahead.

I remember attending a dinner in London about 4 years ago when the British and the French were whistling in the dark telling you how good the Concorde was going to be and how they were going to return to Europe the leadership in the field of aerodynamics where it belonged. They haven't gotten very far with it. I remember when the first DC-8-63 went to the Paris air show, Eastern Air Lines was chartered to take us over there. I was on an exhibit, alongside the mock-up of the Concorde. You had to put people in one door, and bring them out of the center door after viewing the DC-8. When I wanted to go down and go through the Concorde I didn't have to wait 15 minutes.

All right, sir, I just wanted to make sure that I understood you. Thank you, Mr. Chairman.

Mr. HECHLER. On this point, Mr. Perkins, I understand the Aerospace Industries Association has conducted a study examining world aeronautical competition. Is this correct?

Mr. PERKINS. Not to my knowledge, Mr. Chairman.

Mr. HECHLER. You may continue.

Mr. PERKINS. Because of very high development and startup costs of large commercial transports, manufacturers cannot afford to take the risk of incorporating radical or untried features. On the other hand, there has been demand for a long succession of airline transports of larger size and greater performance. In contrast with military de-

velopments, this has led to an evolutionary series of relatively conventional aircraft for which demands for research have been reasonably foreseeable, with the possible exception of mach 3 supersonic transports.

There is now a pressing demand for STOL transport. Airplanes to meet this requirement must be somewhat less conventional. The risks to the manufacturer are considerably greater than for more conventional types in several respects. Flight characteristics cannot be as fully known without first building full scale prototypes, or at least doing a considerable amount of component testing, FAA requirements are as yet undetermined, and traffic control and airport facilities are now inadequate. The management and funding problems associated with these unknowns will not be resolved easily. We urge that DOT and other agencies give these problems high priority.

Many of the questions concerning flight characteristics of STOL aircraft might be resolved if a similar vehicle were procured by DOD, either in prototype form or as a production development program. There would be value to both DOD and DOT in attempting to arrive at STOL aircraft of similar requirements. If a prototype were developed, it should resolve many of the remaining questions about the vehicle itself. This might serve as a basis for a military STOL production program if a requirement then exists. If other critical traffic control and airport problems were resolved during the same time period this might pave the way for a commercial STOL production program.

In recent years the aerospace industry has, for competitive reasons, built its own research facilities insofar as it could financially support them. There is a pressing need, however, for more precise means of determining in advance and with greater accuracy what the full scale characteristics of transport aircraft will be. NASA should evaluate the problems associated with testing of this kind. It probably will involve comprehensive test programs using expensive facilities. We believe U.S. leadership in transport aircraft can be retained, but that there is need for more work by NASA in a number of areas.

The most severe future limitations on commercial aircraft utilization in the United States have to do with operating problems—factors such as traffic control, airport facilities, and noise. These were discussed at length in a report by the Aeronautics and Space Engineering Board of the National Academy of Engineering, which I understand has been submitted to your subcommittee. We concur with the recommendations in that report. Presumably this subject will also be enlarged upon by other speakers. I do want to emphasize, however, that the aircraft industry is vitally concerned that solutions for these problems be found since failure to resolve them can have profound effects on limiting the growth of civil aviation.

Recognizing that the operating problems are especially difficult, we feel there is urgent need for clear allocation of responsibilities nationwide and that the organization with this responsibility must have adequate resources and must manage its efforts in a thorough and systematic way if it is to be successful. Procurement of complex hardware such as aircraft by the military services and of spacecraft by NASA has presented problems of hardware acquisition which, over a period of years, they have organized for and learned how to handle. Civil aircraft operating problems may be even more challeng-

ing because of need for interaction with the public and many local governments. There will also be related technical problems. We believe NASA is the most logical agency to work on those for which it has or can be given the appropriate resources. Industry can and should be used to solve such problems through studies and R. & D. under contract with the Government.

With specific regard to noise, our industry, working with NASA, is engaged in reducing engine noise at its source, in treating the installation in such a way as to reduce noise produced by engines, and in providing flying characteristics which permit climbing as promptly as feasible to altitudes where noise is no longer unduly objectionable. NASA has and can help further to improve techniques for doing these things. We specifically urge the construction of the proposed noise facility at Langley.

In general we believe NASA should (1) do aeronautical research requiring facilities which individual members of the industry cannot afford; (2) provide appropriate access to industry for use of facilities on a noninterference basis; (3) do broad investigations of particular technical areas to provide uniform and consistent background data from which industry can create optimum aircraft design characteristics; and (4) conduct other research in the national interest.

Mr. HECHLER. Excuse me, what does "noninterference" mean?

Mr. PERKINS. I mean by that NASA has their own in-house test programs, and industry has certain requirements for the use of those same facilities and would like to come in and use them.

We believe it is proper for NASA to have control of the scheduling of their own facilities and let industry get in as long as it does not unduly interfere with their own test programs. This has been going on for a number of years, and seems to work out quite well.

Mr. HECHLER. Thank you.

Mr. PERKINS. We would like to make particular reference to the fact that the unitary wind tunnels created some years ago for use by both NASA and the industry have been managed by NASA in the national interest and have served their purpose well. NASA has also made available certain other wind tunnels for use by industry following the unitary pattern. Additional facilities of this kind will undoubtedly be necessary in the future and we feel they should be managed and operated for both Government and industry use in a similar manner.

Whereas a number of aerospace companies have one or more wind tunnels of their own, there is a current and urgent need for reliable data at high Reynolds number—a combination of factors such as large model size, high speed, and high air density—and facilities for testing of this kind appear to be too expensive for any one manufacturer to provide. Provision and operation of such facilities would, we believe, significantly enhance NASA's research capability.

Chairman MILLER. Just a minute. Mr. Perkins, I am very much interested in some of your statements here. You want the Government to assume all of these costs on the ground it is too expensive for industry. If the Government assumes all of these costs, will the cost of airplanes be so reflected in the ticket that I buy to go out to California? Will it reflect what the Government has put into such development? In business in this country we speak about free economy.

But you want to lay the whole burden of developing airplanes and building these facilities on the Government, don't you?

Mr. PERKINS. By no means. When the industry uses the NASA and other unitary wind tunnels for example, it pays for them.

Chairman MILLER. Let's be very clear on that. It pays direct cost.

Mr. PERKINS. It pays the direct cost.

Chairman MILLER. But they don't pay any of the capital costs that go into them, is that true?

Mr. PERKINS. This is at the option of the Government.

Chairman MILLER. Wait a minute. You have not answered my question. The capital costs are not written into it?

Mr. PERKINS. That is my understanding.

Chairman MILLER. I think your understanding is correct.

Mr. PERKINS. As to the other costs of developing airplanes, if you are talking about commercial airplanes, other than this factor that you mentioned, this is all borne by the man who buys a ticket on the airline eventually.

Chairman MILLER. Evenutally. I understand.

Mr. PERKINS. I also point out many of these facilities are needed for the national defense, and are used as a byproduct for commercial use.

Chairman MILLER. I understand the Air Force has some of the biggest wind tunnels in the country.

Mr. PERKINS. Right.

Chairman MILLER. They are for national defense. NASA's facilities are used by DOD. Of course, NASA was created to serve, also, the military forces. There is no question of that.

Now we have taken the burden. I am for all this assistance, because we have seen two modes of transportation that are rapidly declining, rail transportation and water-borne transportation, perhaps because the Government did not do enough research to assist those industries. We can't let that happen to aviation. I don't like the idea of hearing about all these needed expenditures and making your statement appear that a benevolent Government isn't doing anything for aeronautics. I think it has done a great deal.

Mr. PERKINS. I think the ultimate purpose is to aid the Nation and not to aid the industry.

Chairman MILLER. Well, that is true too. Then if we want to follow that to a conclusion, we can say as they do in Russia and other places, if we are going to help the Nation, let's take this layer of management we call private industry out from under us. Let's get this out.

Mr. PERKINS. I think the experience of the United States in operating these things privately is more effective than operating them publicly.

Chairman MILLER. I am not going to argue with you about that. I am just saying you say we have got to do this. I say let's take this out. I am one of the greatest admirers of McDonnell-Douglas, I know Mr. McDonnell and Mr. Douglas, I have worked very closely with them. I am also very conscious of some very fine facilities they have that were built by the Government, built by NASA as a matter of fact, which they continue to use. I don't think the Government has been so harsh, or NASA has been so harsh in the treatment of the aviation industry.

I wonder if the industry hasn't become a little soft, in wanting to lean on Government for all of those facilities and find an excuse by saying the crutch, the Government isn't doing anything for them.

Mr. PERKINS. I would like to point out, Mr. Miller, that the industry, if it had a greater financial burden to carry than it now does in developing new transport aircraft, would find it absolutely impossible.

Chairman MILLER. I think you are right, and I want to say unless we perhaps make some radical changes someplace, the cost of the taxpayers of supporting Government is becoming almost impossible. Let any of you get up and deny this.

Mr. PERKINS. The magnitude of the funding required for these large, new transport airplanes is reaching a point where it is becoming a major question as to whether the largest companies in the country can handle it.

Chairman MILLER. I don't think there is any question about it. The U.S. Lines, for years, operated the Queen of the ocean. They recently had to lay her up. They are not building any more because they can't stand the burden of it. Yet, we don't help them materially.

Mr. PERKINS. So it is a question of whether the Nation as a whole wants to do this kind of thing.

Chairman MILLER. Some of it, and it is getting harder and harder to get money. See what is taking place this morning when a committee knocked $5 billion out of DOD's budget, I think we would be very foolish to say NASA can withstand the thrust placed upon it. And our budget may be going down. I don't see any chance of very many new facilities.

Let's go on. We are in an argument that is not material.

Mr. HECHLER. Mr. Perkins.

Mr. PERKINS. Reference is often made to "proof of concept" programs and "development test vehicles." We believe these can be of great value in bridging the gap between ideas which are shown to be theoretically possible and ones which are proved to be practical enough to incorporate in expensive aircraft development programs. The circumstances surrounding the need for and value of such programs vary considerably. Sometimes it is more appropriate that they be initiated and funded by NASA and sometimes it is better that they be initiated and funded by one of the military services with NASA's help. Industry does considerable "proof of concept" work under contract and can also help in identifying areas of greatest need. We feel that installation of the Whitcomb supercritical wing on a fighter aircraft to prove its characteristics in realistic three-dimensional form is a good example of a valuable "proof of concept" program.

Where a very expensive development test aircraft may be involved (for example, a reentry vehicle or a hypersonic aircraft), adequate advanced research by NASA can go a long way to assuring a successful and fruitful program. There may be need for additional test aircraft of this kind. For example, as part of the future space program NASA plans to introduce reusable launch vehicles and reusable orbiting reentry vehicles. Since these must maneuver in the atmosphere, land safely at predetermined places on earth, and be reusable repeatedly with little or no refurbishment, they necessarily take on many of the requirements and characteristi[illegible] an airplane. In fact, it may be found that from a technical stan[illegible] it may be more

difficult to meet the airplane-like requirements than the space-craft-like requirements. We can therefore foresee that such vehicles will be replete with both known-unknown and unknown-unknown problems. It would seem prudent under these circumstances that NASA make a particularly concerted effort to anticipate technical problems and carry out R. & D. required for their solution and, in addition, to seriously consider the need for prototype hardware which will bring out in the laboratory and in economical flight form as many as possible of the technical problems of the type which cannot be foreseen. Something like the X–15 hypersonic test vehicle might be a step in this direction. The cost should be small compared with the cost of the full-scale reentry vehicle planned.

Earlier testimony before your subcommittee indicates NASA is being approached by other Government agencies for more and more research unrelated or only indirectly related to its primary roles in aeronautics and space. We feel that NASA does have technical capabilities for a wide variety of such research but should not be expected to support a large amount of it unless its funds are appropriately increased for the purpose and additional facilities are provided as necessary.

This raises the often-discussed issue of whether NASA should accept funds from other agencies for such purposes. Most of us in industry feel that NASA has been productive under the method of funding used. We feel that NASA, as the Agency responsible for carrying out the research, must be able to realistically plan ahead for acquisition and use of facilities. Also, from a technical standpoint, NASA is often in a better position than the requesting agency to judge the most probable value of results to be expected from various research proposals, and hence the priority they deserve. Willingness of another agency to provide funds is no assurance that a proposed research program will be worth undertaking. We therefore recommend that the present method of funding be retained.

It may be helpful to describe further R. & D. done by the aerospace industry in relation to aeronautical research by NASA. Over the years an unusually effective working relationship has been forged between the aerospace industry and NASA, in which each can do what it is best equipped to do. In general NASA carries out broadly extensive and systematic investigations which provide a data base and can be useful for any of a wide variety of aerospace products. In general, industrial firms cannot afford such broad investigations and focus on particular product objectives within their capabilities. In addition to research of this kind, the aerospace industry does a great deal of related technical work such as concepts and proposals for new products, preliminary design studies and analyses, trade-offs involving evaluation of the risks and benefits of alternate designs, detail design and integration, laboratory and flight testing and many others. These activities require large and capable technical staffs and facilities. Nevertheless, the aerospace industry believes it essential that the broader and more fundamental investigations should be carried out by NASA and that the results of these investigations should be available as starting points in making design studies and developing optimum designs to meet specific objectives for military and civil aircraft.

The aerospace industry does far more research and development than most industries because of the unique and highly technical nature of its business and the fact that its technologies are expanding so rapidly.

Mr. HECHLER. Excuse me, Mr. Perkins. Did anybody ever try to quantify that by percentages?

Mr. PERKINS. I have seen charts showing that, but I am not certain of their validity.

Mr. PERKINS. Such work is generally classified either as independent research and development (IRAD) or contract research and development (CRAD).

IRAD is that research and development which contractors must do on their own initiative to remain up-to-date and technically competitive in this fast-moving industry. Any aerospace company which did not devote considerable effort and resources to IRAD would soon find itself hopelessly behind the times technically. We consider such work vital to the future of our individual companies and to the ability of the United States to compete with that of other nations in aeronautics. We urge the continued recognition by Congress of the importance of IRAD.

CRAD contracts are usually relatively small. Development of major systems are not included in this category. Contracts for R. & D. are let by many agencies of the Government on the basis that the contractor selected can carry out the work more efficiently than anyone else because of related experience, availability of special facilities, availability of personnel with special capabilities, or for other reasons. The use of CRAD has grown considerably in recent years. We believe this is largely because experience has shown this to be a most effective way to accomplish much of this kind of work.

With respect to long-range research needs, except for those few requirements which result from unanticipatible technological breakthroughs, most long-range needs will evolve from extensions of existing research programs. Continued coordination between NASA and industry carried out through the NASA advisory committee structure has resulted in identification of a significant backlog of unfulfilled research requirements. Much of this work has been delayed because of funding limitations. One example is need for systematic data on the aerodynamic characteristics of airfoils of less than 6-percent thickness.

Where new large facilities will be needed and require a long time to put into operation, NASA must plan far ahead. An example might be a large wind tunnel for high Reynolds number testing. Of course all of the more fundamental research is predicated on long-term goals. A possible example of such research might be the investigation of the fundamental nature of burning to learn what it takes to make fuel burn better.

We have prepared several charts (figs. 1 through 3) listing typical priority research we believe to be needed to keep the United States competitive in aeronautics.

Exhibit A has also been prepared as reference information to explain many of these in more detail.

I have simply three charts of this kind, and I want to point out two significant words—"typical" which signifies that this is by no means a complete comprehensive list, and "priority," in that these are things that are not necessarily arranged in a priority order as shown, but

we have listed only those things which we do consider priority areas. We have indicated most of these apply to military aviation, to transport aviation, and to general aviation.

Now, I don't want to bore you with going into detail on each of these items, but exhibit A gives a discussion of each of the line items shown.

Mr. HECHLER. Where does collision avoidance come in?

Mr. PERKINS. Collision avoidance is something that we believe is primarily the concern of DOT within the Federal Government and, as such, is not primarily an issue between industry and NASA, and so we have not listed it.

Mr. HECHLER. That is rather unfortunate. We consider that to be a rather important area.

Mr. PERKINS. We did have a chart that I left out in yesterday's review of this presentation, which did show operating problems. We decided to confine ourselves to things relating more directly to NASA and industry.

Mr. HECHLER. I certainly hope you consider safety being one of your very prime considerations.

Mr. PERKINS. We certainly do.

If the airspace of the future is to accommodate the expected increase in the number of flight operations, a transition to area navigation will be essential. Area navigation permits the total airspace to be used for flight operations instead of the relatively narrow corridors that aircraft now fly. Clearly, area navigation shows great promise both in increasing flight safety and in expanding the capacity of the airways.

Chairman MILLER. Mr. Chairman, isn't that really DOT's problem? We are not in the operating business. It is up to them, isn't it? It is up to us to be concerned with the research on any facilities, the factors that would enter into it. But when it comes to operations, the proficiency of operation, let DOT take care of that.

Mr. HECHLER. This reminds me of my conversations with the manufacturers of coal-mining machinery, who all say, we are not manufacturing lifesaving equipment, we are manufacturing production equipment.

Chairman MILLER. Well, that is true. Frankly, I don't see the parallel between them, Mr. Hechler. Under the law the Department of Transportation regulates the flying of airplanes and things that go into them.

NASA is concerned with systems that can be developed to take care of these things, but we are not going to encroach on DOT until these people do it.

Mr. HECHLER. You may proceed, Mr. Perkins.

Mr. PERKINS. The first chart, figure 1, relates to aerodynamic problems, the second, figure 2, propulsion problems, which you can see here. The third chart, figure 3, we might put up is the structures and materials area.

There are a lot of other areas, but these three, in general, and the items listed under them, are among those that we consider typical higher priority areas.

Mr. HECHLER. These charts are all submitted for the record, is that correct?

(The charts referred to follow:)

TYPICAL PRIORITY RESEARCH NEEDED TO KEEP THE U.S. COMPETITIVE

	Required for		
	Military aviation	Transport aviation	General aviation
A. AERODYNAMICS			
1. Systematic data on wings, bodies and interactions	X	X	X
2. Power plant installation data, including inlet and exhaust configurations	X	X	X
3. Transonic phenomena	X	X	X
4. High lift devices for STOL aircraft	X	X	
5. Ground proximity effects with STOL aircraft	X	X	
6. Correlation of wind tunnel and flight test data	X	X	X
7. Test data at high Reynolds numbers	X	X	
8. Spin recovery Criteria	X	X	X
B. PROPULSION			
1. High tip speed fans and compressors	X	X	X
2. Higher temperatures	X	X	X
3. Improved materials and processes	X	X	X
4. Noise reduction	X	X	X
5. Improved engine-propulsion system-aircraft integration	X	X	X
6. Advanced turbojet/fan technology	X	X	X
C. STRUCTURES AND MATERIALS			
1. High strength composites using various fibers and matrices	X	X	
2. High strength and lightweight metal alloys	X	X	X
3. High temperature materials	X	X	
4. High temperature adhesives and sealants	X	X	
5. Corrosion protection	X	X	X
6. Airplane fatigue	X	X	
7. Advanced material applications	X	X	X
8. Landing gears	X	X	X
9. Nondestructive testing	X	X	X

Mr. PERKINS. Yes, including the text, Exhibit A.

I might read, at this point, the introduction to Exhibit A which describes these:

Examples of advanced research activities in aeronautics in which more work is required are enumerated herein. As such, this list is intended to be typical but not all inclusive, nor does it necessarily comprise a balanced judgment of relative requirements. Some of this is research that is clearly in NASA's area of special competence and responsibility. Some of it is better done in industry laboratories.

The formulation, review, and continued coordination between NASA and industry, carried out through NASA's advisory committee structure, has identified a backlog of unfulfilled research requirements, much of which has been delayed due to funding limitations. Most, if not all, of the items discussed in this exhibit have already been the topic of many deliberations of the NASA advisory committees.

In presenting this list, it is hoped that your Subcommittee will get a picture of the breadth of the unfulfilled research requirements demanding national attention. I would like to to repeat that NASA knows of most of these requirements and has not fulfilled them because of current budgetary restrictions. We recommend that the NASA programs continue to be formally structured through the NASA advisory committees.

There are many other problem areas in the aeronautical field notably those in aircraft operations such as aircraft control and collision avoidance. There are even more having to do with the airport and its relation to the community. The DOT is attempting to define national programs dealing with these problems and we suggest that NASA has the facilities and talent to make substantial contributions once the national programs have been defined.

A. AERODYNAMICS

1. Systematic data on wings, bodies and interactions

Industry needs much systematic data in order to make complete systems analyeses and design trade-offs to optimize these aircraft for their intended use. Key technology areas where NASA should work, or increase its effort on an accelerated scale, are:

a. Airfoil Section Data

There has been very little airfoil section data obtained since the work done on laminar flow airfoils in the early 1940's, and none on airfoils thinner than 6%. We need systematic research on thin airfoil sections with various leading and trailing edge devices at both low speeds and high subsonic speeds up to and beyond the stall. This data is needed as a prelude to understanding the shock boundary layer interactions at high subsonic speeds and high angles of attack on three-dimensional wings. It is also needed to obtain higher lift coefficients on thin, highly loaded wings so that lower and, hence, safer approach and landing speeds may be achieved. We need to discover airfoil section modifications to reduce the drag at high lift coefficients and high subsonic Mach numbers such as Whitcomb's supercritical section.

b. Configurations and Interactions

A variety of systematic data are required on characteristics of bodies and other aerodynamic shapes and influence of individual elements on each other in such areas as:

1. High supersonic and hypersonic configurations.
2. Hypersonic flow interaction effects.
3. Flow field prediction techniques.

2. Power plant installation data, including inlet and exhaust configurations

The growth of aviation has been paced to a considerable measure by the development of power plants with adequate performance and reliability.

High on our list of critical technologies affecting military and commercial aircraft design are those involving the integration of the propulsion system into the aircraft, notably:

a. Inlet Research

Work needs to be done on other than axisymmetric inlets. We need to develop inlets that are a component part of a complete airplane. These inlets should be able to operate at subsonic and supersonic speeds up to at least M=4, with high recovery and low drag, and a minimum of complexity in the form of moving parts. Such inlets should also have low distortion throughout the speed range when operated at high angles of attack and yaw. In this regard we need additional research on the phenomenon of the rotating compressor stall, particularly on fan engines. We need to be able to define the engine's tolerance to static and dynamic distortion with considerably more accuracy than we do now. We also need to know quantitatively the effect of thermal distortion, and gun and rocket gas ingestion on the engine's tolerance to stall in order to optimize the aerodynamic design of our aircraft.

b. Jet Exit Research

One of the largest sources of drag on supersonic jet aircraft is the jet exit. The adjustable nozzle required for afterburning and the wide jet pressure ratio variation causes excessive drag at off design conditions such as subsonic cruise and loiter. In addition, the external interference effects of twin and multiple jet installations, horizontal and vertical tail surfaces, and forebody flow characteristics combine with the internal jet efficiency which is affected by such things as nozzle spacing, and diameter ratios, secondary air, expansion ratios to form a matrix of variables which cannot be solved with the present jet exit data available to the designer. We need additional research on promising new nozzle designs such as the two-dimensional plug or wedge nozzle.

3. Transonic phenomena

Advanced airfoil concepts, such as the supercritical wing, as well as considerations of sonic boom avoidance have recently focused attention on configuration development problems for Mach numbers slightly above and below 1.0 (roughly .95–1.20). The major problems in this speed range appear to be those of overall configuration integration and, in particular, the integration of the propulsion package into the total configuration. Specific areas for study recommended for inclusion in the complete program are:

Limitations and accuracy of far-field analysis methods to obtain drag at low supersonic Mach numbers;

Fuselage engine installations, including effects of boundary layer ingestion;

Axisymmetric engine nacelle shapes for low shock drag;

Engine jet exhaust simulation effects;

High lift systems for advanced airfoil shapes.

We feel that NASA should give consideration to increasing substantially its total testing capability for transonic wind tunnel work, which underlies all military and commercial transport aviation.

4. High lift devices for STOL aircraft

Although the aerodynamic principles of jet flap wings are now well established and, in the short terms, it should be possible to make useful estimates of lift, pitching moment, etc. of STOL aircraft wings of moderate aspect ratio, sweep and jet deflection of internal blown systems, experimental data on specific configurations still have to be relied on for establishing the effects of external blowing (i.e., external blown jet flaps). The lack of suitable analytical methods and the failure to date to successfully correlate the lift augmentation due to external blowing is due, in part, to a lack of experimental data of a general and systematic nature. These data are required to permit the formulation of an analytical/empirical approach that would make it possible to estimate the effects of geometry (e.g., engine location and wing planform) on jet impingement and in turn the resulting turning and spreading of the jet efflux. It is therefore recommended that further experimental and theoretical research directed toward this end be undertaken on external blown jet flaps.

5. Ground proximity effects with STOL aircraft

The flow behavior due to ground proximity with jet flap wings of finite aspect ratio has proved substantially different from that observed in early small scale two-dimensional tests. Only simple mathematical representation of ground proximity for two-dimensional jet flap airfoils have so far been formulated. There is yet no realistic theoretical treatment for jet flap wings with the jet path in close proximity to the ground. STOL operation within ground effect is essentially a transient phase, so the application of "stationary" model results and "quasi-steady" analytical methods need further justification by dynamic model tests and flight tunnel comparisons. It is recommended that an experimental program be initiated to explore the possible limitations in the use of "stationary" model results.

6. Correlation of wind tunnel and flight test data

NASA has initiated and has made a progress report (AIAA Meeting, July 14–16, 1969, Los Angeles, California) upon a series of investigations to determine the extent to which the wind tunnel results of the major government and commercial wind tunnels in the U.S. agree. While this is a highly commendable effort it goes without saying that wind tunnel data correlations are but the first step toward the ultimate goal of obtaining accurate full-scale flight characteristics from extrapolated wind tunnel results. This goal requires a continuing program to correlate flight test results as they become available with predictions made using extrapolations of wind tunnel data. NASA has already participated in the wind tunnel evaluation of such aircraft as the C–5A and the F–15 and it is strongly urged that NASA continue its participation in these programs through the flight test phase and the correlation of the results obtained with the wind tunnel data. It is further suggested that this general program of data correlation be extended to include other existing aircraft, such perhaps as the C–141 and possibly commercial jet transports (contingent upon the manufacturer's willingness to release his flight test information.)

These correlations need to be detailed studies which isolate the various basic components of the flight drag, i.e., zero-lift, drag due to lift, trim drag and compressibility drag, and relate them to wind tunnel data, exploring the test conditions and techniques used to determine the wind tunnel values. A realistic assessment needs to be made of whether or not the various tunnels used can properly account for wall effects, etc., and if not, what portions of the drag can be used with any degree of confidence. For example, the aerodynamic efficiency factor "e" is a strong function of tunnel porosity. Is the compressibility drag affected by porosity? Since the wind tunnel cannot be used to estimate the "roughness" drag of the full-scale airplane, such a study would be extremely useful in determining the actual roughness factors associated with standard manufacturing techniques.

It is recommended that detailed testing be conducted under a joint NASA industry program, using a jet transport aircraft as a reference, to more clearly define the relationship between low speed-high lift drag characteristics as measured in flight and in a wind tunnel. In particular, the high Reynolds Number tunnel test should utilize a balance designed for high sensitivity to drag; further,

a detailed model support system interference tare program should be conducted. The flight program should consist of tests to obtain drag data in level flight with all engines operating. It is felt that the correlations from the results of this program can greatly enhance the utility of high Reynolds Number wind tunnels in the determination of low speed drag.

7. Test data at high Reynolds numbers

The demand for greater accuracy in predicting performance and maneuverability of aircraft in landing, takeoff, and flight conditions has increased the need for full scale Reynolds Number simulation as mentioned above. The NASA 11-foot transonic tunnel and 12-foot low speed pressure tunnel at the Ames Research Center, both constructed some years ago, are the most advanced facilities available today for such testing. Neither of these, however, can provide full-scale Reynolds Number data on military and civilian designs now on the drawing boards. We need to accurately study the interaction of boundary layers and shock waves in transonic flows, where the flow is marginally at the stability limit, and feel that this is being seriously hampered at present.

The construction of two new high Reynolds number wind tunnels or other means to accomplish the same results is therefore a matter of high priority nationally. The decision of how big and how expensive these facilities should be must be weighed in the balance of sound economy as well as dynamic competitive motivation to obtain a greater national capability in this important field of aerodynamics.

8. Spin recovery criteria

While many may think that everything has been done that needs to be done relative to spin recovery, it would be our suggestion that this area be reopened. Many aircraft accidents today are the result of stall spins. To the best of our knowledge from our criteria, airplanes which violate present criteria have good spin recovery. Contrarywise, some which meet today's criteria do not have acceptable spin recovery. The effects of ventral fins and horizontal stabilizer strakes should be investigated.

B. PROPULSION

In the following paragraphs we will give you an overall summary of what we foresee as the developmental opportunities in aeropropulsion. Before proceeding, we would like to draw for you a distinction between the portions of this program which can be pursued most productively in our federal laboratories and those which can be pursued most effectively in the engine industry.

Over the years. NASA has made great contributions to all branches of aeronautical engineering in the development of overall theory and the accumulation of data banks of generally applicable experimental information. Industry, on the other hand, has traditionally concentrated on the reduction to practice of operational systems.

For example, the design of advanced high pressure ratio, high Mach number compressors of the type needed in the future will require new theoretical and experimental information on the characteristics of blading operating under such conditions. Data of this type is of *general* applicability and can be used over and over in numerous design and developmental efforts. The accumulation of such information is most profitably done on a national basis in federal laboratories. On the other hand, problems which are specialized to the particular engine system are best solved, on the job, by the engine system manufacturer.

As a statement of policy, we therefore urge that in addressing the general requirements outlined in the following testimony the federal laboratories concentrate on the evolution of generally applicable theory and associated generally applicable experimental information while the engine industry concentrate on the problems which tend to be peculiar to the development of operational systems.

The dominant trends in propulsion system technology requiring research and "proof of concept" development are outlined below for implementation within the context of the roles of NASA and industry discussed above.

1. High tip speed fans and compressors

a. Advanced research is needed for fan tip speeds to increase for subsonic and near sonic Mach number aircraft use and for mixed mission supersonic use.

b. Compressor tip speeds also need to increase.

c. Stall margin and distortion compatibility need to be improved. New analytical design techniques and new blade shapes need to be developed to maintain high efficiency.

2. Higher temperatures

a. The next major technology effort in turbine inlet temperatures should be directed toward higher temperatures. The focus should be on advanced, long-life, air-cooled turbines and combustors.

b. Advancements in high-temperature technology decrease fuel consumption in all types of engines. The ultimate will be stoichiometric turbine temperatures. Exploratory work in this regime must be started in this time period.

3. Improved materials and processes

a. A revolution is taking place in composite materials: the high strength, high stiffness filaments like boron and graphite in a suitable matrix of epoxy, polyimide or aluminum. Vigorous development of this technology in fan blades, and engine static structural components is essential—and later, for high-temperature components.

b. Significant progress is possible in higher strength superalloys and their application to turbine blades, compressor and turbine rotors. Much of this progress will come from new processing development such as powder metallurgy, activated diffusion bonding, inertia welding, and directional solidification in castings.

c. Lower cost, longer life, more reliable, lighter weight engines depend greatly upon technology improvement in this field.

4. Noise reduction

This will be covered separately in the Aerospace Industry Association testimony on 10 December 1969.

5. Improved engine-propulsion system-aircraft integration

Propulsion system technology is on no plateau. The spectacular advancements of the last decade can be matched in the coming decade if advanced aeronautical research and development obtains the required recognition and support. Coordinated effort is required by the engine manufacturers and the aircraft manufacturers assisted by NASA in areas such as the following:

a. In the subsonic aircraft field, for example, we must press forward with short, more compact advanced turbofans adaptable to low drag nacelle designs; we must determine the best STOL transport turbofan installation design; we must establish a lightweight STOL reverser system capable of operation down to 10 knots; we must develop advanced controls and sensors.

b. In the mixed mission supersonic aircraft field, for example, we need further intensive work on inlet engine compatability—a challenge to the engine designer and airplane designer alike. Also, great progress is still possible in the design and marriage of advanced jet nozzles with the aircraft afterbody for reduced closure drags and reduced interference drags.

c. Turbine inlet temperature sensors are needed for gas turbine engines.

Our emphasis on the foregoing priority technology areas in the next five years does not mean that we advocate neglect of other areas necessary for balanced progress. Important work is needed on electronic controls, advanced accessories, fuels and lube, fracture mechanics, computation techniques, bearings and seals—to name a few. Furthermore, specialized work on advanced fuels, hypersonic flight, VTOL lift fans and others must proceed.

6. Advanced turbojet/fan technology

The following are typical of specific advanced engines intended for service in the time period between 1976 and 1980, engines which should be the focal point for advanced technology by NASA. The development of the engines, per se, would not, in our opinion, be a NASA responsibility.

a. Advanced subsonic high bypass turbofan engines are required for use as the main propulsion engines of turbofan-powered military and commercial STOL transports, V/STOL transports, and also CTOL transports.

High speed fan and compressor technology, advanced nickel superalloys and composite materials, advanced noise reduction technology and advancements in engine-aircraft integration are required to produce such a versatile STOL, V/STOL, and CTOL propulsion engine.

b. Advanced small engines with advanced materials and high-speed turbomachinery should be taken through proof-of-concept testing for military applications, with possible extension to general aviation.

c. Proof-of-concept work on an advanced large lift fan and its closely integrated gas generator, with technology more advanced than current developments, will be essential to military and commercial V/STOL transports entering service in

the near-1980 time period and useful to STOL transports if the lift fan STOL approach is followed. Composite materials, high-speed turbomachinery, advanced noise reduction features, and advanced engine-aircraft integration features are all essential to achieve reliable, long cyclic life designs.

C. STRUCTURES AND MATERIALS

In this technology, much research has been done in the aerospace industry and materials industries, supported where appropriate by contracts from military departments. It is fair to say that NASA's role in structures and materials has not been the dominant one. Nevertheless, NASA has made noteworthy contributions to this technology and we feel that NASA's efforts should continue on a selective basis.

1. High strength composites using various fibers and matrices

The use of high modulus high strength material such as boron and graphite in advanced research and technology will provide large payoff in future aircraft of all types. We urge continued emphasis on research of structural designs which take full advantage of these materials properties.

2. High strength and lightweight metal alloys

Better lightweight alloys and more effective use of titanium may well be accelerated by renewed efforts by the basic metals industry in conjunction with NASA. R&D efforts leading to a deeper understanding of mechanisms of fatigue, corrosion and cracking should yield improved utilization of advanced materials.

3. High temperature materials

High strength to weight ratio materials that can be used at the high temperature occurring in jet engines and on the surface of supersonic and hypersonic aircraft are urgently needed.

Great strides have been made using composite materials of organic resins and aluminum matrices reinforced with filaments of boron, silicon carbon, beryllium and graphite. The reinforcing materials are excellent at very high temperatures but the matrix in which they are imbedded is not.

Continued advanced materials development effort is needed to remedy the deficiencies still existing in the matrix at high temperatures. The end result is expected to be a practical fabrication technique for high temperature carbon/graphite composites.

4. High temperature adhesives and sealants

New polymer developments are providing the basis of research in the field of adhesives and sealants. Titanium alloys with composite substrates are useful for the very high temperature regions of supersonic aircraft. The bonding of alloy to substrate is a major problem being addressed by current R&D. The approach is through the development of thermally stable polyimide adhesives.

Sealants for fuel tanks located in the high temperature regions of aircraft wings is another major problem. The sealant must be thermally stable and in addition it must be chemically compatible with hydrocarbon fuels at high temperature. Continued research on thermally stable, chemically compatible resins is needed and will lend to the development of satisfactory high temperature tank sealants.

5. Corrosion protection

Development of a highly resistant corrosion protection system for aluminum alloys which does not have a deleterious effect on the fatigue properties of the material remains an important area for joint effort by NASA, the military, and industry.

6. Airplane fatigue

While it is known that NASA is currently working on a VN/VHN program, it is suggested that some effort be expended to try to establish for worldwide use, spectrums of gust exposure which would provide design criteria for use on aircraft as it relates to fatigue life.

7. Advanced material applications

The development of new materials with major improvements in mechanical properties and lower cost will probably require government funding because of the limited market for aircraft materials producers.

Structural weight can be reduced through accelerated government/industry development of advanced materials applications. This will require a government/industry program to build prototype components of new materials to demonstrate their practicality. Much of this work in the past has been done by industry under military sponsorship. A similar relationship between industry and NASA would enhance the effectiveness of its structural research program.

8. Landing gears

a. Rough terrain landing gear system—programmable shock strut, high flotation tires and wheels, load alleviating devices, sensor and logic systems all require attention.

b. Advanced nonconventional braking methods—air or fluid pump or turbine systems—deserve investigation.

c. Improved stopping systems are needed for small aircraft—anti-skid, thrust reversers, etc.

9. Nondestructive testing

Research is required to adapt the techniques of physics anad electronics to the nondestructive testing of aircraft structures for field inspection and manufacturing inspection. The development of composite structures using various chemical adhesives is being paced to a considerable extent by the development of these new techniques to assure the fidelity of chemical bonds without destroying the part being checked.

The list of potential programs which we have suggested does not in any way imply a massive expansion in the NASA total budget. At present the budget for aeronautical research is so small, as a percent of the total, that even a major increase would only have a modest dollar impact, perhaps 2 percent or less of total NASA budget. Since it is such a small percent it is vulnerable to loss in overall administrative cuts and therefore it needs not only to be expanded, but carefully protected once established.

Mr. HECHLER. Amen.

Mr. PERKINS. May I quickly summarize by repeating several primary points. The future position of the United States in relation to the rest of the world in military and civil aviation depends on aeronautical research by NASA and the aerospace industry. To retain a satisfactory competitive position in the future, it is essential that NASA have the personnel and facilities to carry out an accelerated program of advanced aeronautical research. For the same reason it is essential that the aerospace industry be given more opportunities to develop and test actual hardware.

Thank you, Mr. Chairman, this concludes my statement.

Mr. HECHLER. Mr. Perkins, we appreciate very much this very illuminating statement which you made, which opens up many areas of additional discussion.

At the last meeting of the subcommittee we had a very heavy unbalanced line over here to the left, and we were outnumbered on my party's side by three to one. This morning we are very pleased to be honored not only by the chairman of the full committee, but by the gentleman from Missouri, Mr. Symington, who has long taken an active interest in aeronautics. I would like to recognize the gentleman from Missouri for any comments or questions he cares to make or pose.

Mr. SYMINGTON. Thank you very much, Mr. Chairman. I really am here, Mr. Perkins, on sufferance, rather than as a member of this subcommittee. I am on another subcommittee which is currently meeting and listening to Mr. Staats of the General Accounting Office, and should perhaps return eventually. But I wanted very much to come and welcome you here, at least as a member of the whole committee,

and as a Representative of your area and your own good self, and to say how proud I am as a Missourian, and as a St. Louis Countian, to have a gentleman of your caliber and standing and background appear before this committee and give a statement of this significance.

I am certainly interested in the aeronautical aspects of NASA's work, as I am sure we all are on this committee, and want to say to you how grateful I am to you for taking the time to prepare a statement of this character and present it to this subcommittee.

I will say again how grateful I am to the chairman of the subcommittee and the chairman of the whole committee for letting me listen in.

I do, Mr. Chairman, have to get back, I think, to my other subcommittee, because the line is considerably unbalanced there at the moment. With that I will excuse myself.

Mr. PERKINS. Thank you.

Mr. HECHLER. Thank you, Mr. Symington.

Chairman MILLER. I would like to make a statement before Mr. Symington goes. California owes a great debt to Missouri and St. Louis County, to a man by the name of Benton who represented this area in the Senate of the United States and was responsible for, as much as any other man, perhaps, for the development of the West. We in the West although we are very generous, we are very happy to return to St. Louis County and to stimulate it with its great aerospace company that is now associated with McDonnell.

Mr. SYMINGTON. Thank you very much, Mr. Chairman.

Mr. HECHLER. Mr. Goldwater, do you have some questions?

Mr. GOLDWATER. I might ask one question, Mr. Chairman, of Mr. Perkins.

In your statement, you mentioned there was a need for organization on a national scale to meet aeronautical research and development. I am wondering how you envision this structure should be organized, and where should the area of leadership fall? What agency should do the leading and the managing, the long-range managing, or set policies?

Mr. PERKINS. Are you referring to civil transportation problems, civil aeronautics problems?

Mr. GOLDWATER. Well, in your statement you mentioned that there was a need for something based on a national level.

Mr. PERKINS. I referred there to the future problems of air transportation, specifically civil air transportation: Collision avoidance, traffic control, airport facilities, noise, air pollution, and so forth. Problems like this are of national scope and we see no hope of their being readily solved without more national action than has been taken. I don't think we, from the standpoint of the aerospace industry, feel that we should tell the Government which agency of the Government should take this responsibility.

Mr. GOLDWATER. Of course, you have to work within things as muddled as they might be. It seems there is a tremendous overlapping of interest. Or even of responsibilities. I think this has probably been a problem that has been around for some time. We can only look at it from our side, but perhaps having someone that has to work with the complications that are involved, how might an organization be set up to better coordinate it?

Mr. PERKINS. As I understand it, and I am not personally intimately familiar with some of the aspects of this, but as I understand it DOT was established with this as one of its major objectives, to take on the overall management in this area. We know of no reason why that isn't a logical approach. We have addressed ourselves primarily to the relation between DOT and NASA in technical areas and between our industry, and either one of them, in technical areas.

We feel the overall management seems properly placed in DOT, but that NASA can be of great help in this connection on technical problems.

Mr. GOLDWATER. In other words, NASA should be subservient to DOT?

Mr. PERKINS. That is an awfully broad way of putting it, but I think in regard to certain technical investigations that is what I am saying, yes.

Chairman MILLER. Would you yield, Mr. Goldwater?

Mr. GOLDWATER. Yes, sir.

Chairman MILLER. Under the usual way we operate the Government, wouldn't DOT have to request NASA to do some of these things?

Mr. PERKINS. Yes.

Chairman MILLER. When we talk of DOT, it is really FAA within DOT, that you are concerned with. In the past all those people who have been down there, have they been the type of people amenable to doing anything for themselves, or would they rather go ahead and do it on their own, or be asked? You know who I am talking about. He is a great person, a very good friend of mine, for whom I have great respect. We can get these things worked out. Money is one of the factors. It is very easy to say now we are going to be working with a very tight budget.

Mr. PERKINS. We in industry feel there are a lot of cooks in this situation, and we would rather not complicate the problem by injecting too much of ourselves into it, except where we can be helpful.

Chairman MILLER. This is going to be your problem. This is where you are going to make money, or hope to make money.

Mr. PERKINS. We are extremely interested in having the answers.

Chairman MILLER. At the same time, we recognize it. You are going to say, "Congress, you do it, you give us the money to do it." But you don't want to get snared if the thing doesn't go too well by coming out and actually helping. I think you do, but you don't express it very well. The people I know in your industry, I think are sympathetic.

May I ask you offhand have you ever read Mr. Servan-Schieber's book?

Mr. PERKINS. No, I haven't. Do you recommend that I do?

Chairman MILLER. I don't think you are so concerned with American industry in Europe, but he has one chapter in it on the Concorde that I would recommend that you read.

Mr. PERKINS. I will do so.

Chairman MILLER. I might cite the gist of it. England and France, in their effort to try and overcome the lead, almost bled themselves white, if you were in these places when they were asking for $185 million from England, and $185 million from France. Then he said, what have they done? They built it out of the wrong kind of metal. It can't go more than mach 2 or it will burn itself up. What do you build DC–8's out of, is it aluminum?

Mr. PERKINS. Aluminum primarily.

Chairman MILLER. Do you use a lot of titanium and steel?

Mr. PERKINS. Some.

Chairman MILLER. It can stand more than mach 2?

Mr. PERKINS. You are referring to the SST.

Chairman MILLER. Oh, yes. He said within 4 to 5 years the Concorde will be a second-class airplane. This is European technology at the present time.

Mr. PERKINS. Do you want me to comment? I would rather not.

Chairman MILLER. I don't want you to comment. I shouldn't criticize European technology.

Mr. PERKINS. One of our extremely capable competitors is intimately involved.

Chairman MILLER. I know they are extremely great competitors. The ones I think we have to consider is that they have not done very much in this field, but what we have to consider eventually is Japan.

Mr. PERKINS. They are not to be underrated.

Chairman MILLER. At no stage of the game. They have some laboratories that are now working and I visited them.

Mr. PERKINS. Yes, I have a great admiration for the ability of the Japanese.

Chairman MILLER. I am through. Thank you, Mr. Goldwater.

Mr. GOLDWATER. I have no further questions.

Mr. HECHLER. I was particularly interested, Mr. Perkins, in what you were saying on page 12 about independent research and development. I wondered if you would expand on what the importance of independent research and development is, both to the industry and to the Nation, and perhaps talk about what this will mean to the future.

Mr. PERKINS. I would be very happy to. This is a subject that we consider of vital importance to both the industry and the Nation. It is the point at which many new ideas start. It is the single activity, from a technological standpoint which is the most vital to the survival of the company involved, and we consider it an absolute necessity in doing business in the same way that we consider it a necessity to keep accounting records, or to have proper manufacturing facilities.

There has been quite a bit of discussion about IRAD recently. Some of the discussion has been based on a fundamental misunderstanding of how the costs are allocated. It has been assumed in some quarters that a company which does both Government work and private commerical work charges all of its independent research and development to ovearhead which is all charged to Government work. This is definitely not true. IRAD is equitably allocated between commerical and military work through accounting policies and practices which are approved by the Government. Further, the Government, in order to establish additional incentives for control of IRAD by the contractor, requires contractor sharing of the portion of IRAD which is allocated to Government contracts. This sharing of the Government's allocation is accomplished by negotiation each year between the contractor and a DOD "Tri-Service Board." NASA is also involved in these negotiations. In addition, the Government has a capable team of technical people review the work done by each company in IRAD from several standpoints.

In the case of my own company, for example, currently approximately 50 percent of the cost of such work is borne by the company either through allocation to commercial programs or through sharing of the Government's allocation under the Tri-Service Board agreement.

The part which is charged to the Government is recognized by the technical review teams they send out to review these things as being the kind of work the Government believes worthwhile. Much of this work is of a creative nature that if it were not paid for somewhere it would not be done, and if it were not done, new ideas would not spring out. These ideas are the starting points of many of our weapons systems. Not all the ideas for new weapons are, by any means, created within the Government. Many of them come from industry. This is where it comes from.

Mr. HECHLER. Mr. Perkins, I think you are touching on a very important subject. In looking at the clock, I note our time is starting to run short. I wondered if there was anything more on this subject that you could submit for the record?

Mr. PERKINS. We would be glad to.

Mr. HECHLER. Once again, I want to express the appreciation of the committee for your very useful remarks here this morning.

If there are no questions from members of the committee we will proceed with the second witness this morning, Mr. Mark E. Kirchner, manager, V/STOL Transport Branch of the Boeing Co.'s VERTOL Division, also speaking for the Aerospace Industries Association of America.

(Additional information submitted for the record:)

INDEPENDENT RESEARCH AND DEVELOPMENT

Independent Research and Development (IRAD) effort, as discussed herein, is that portion of R. & D. undertaken by DOD and NASA contractors which is conducted in addition to that required in the specific performance of contracts or grants. IRAD effort has traditionally been viewed as in the national interest because:

1. The independent judgment of scientists and engineers in industry as well as those in government should be beneficially utilized in the determination of the nature and level of technical effort to be expended. Government cannot, nor does it presume it can, conceive all the ideas worth pursuing and therefore it does not endeavor to act as sole judge of the potential of all new concepts. The alternative to independent direction of IRAD would be all-pervasive government planning and control, which would constrain valuable sources of new ideas.

2. IRAD is undertaken by a company on its own initiative, applying its best business judgment, to update and develop technological capability that will effectively meet anticipated needs of the government and other customers for advanced products. Without the new concepts and knowledge which stem from IRAD, the government would have difficulty finding contractors capable of meeting technical requirements for advanced programs.

3. IRAD assures having technology adequately at hand to permit both government and industry to contract for advanced new programs without excessive risks due to technical "unknowns".

4. Our free enterprise system requires competition of ideas. Parallel IRAD effort by more than one contractor is fundamental to effective competition. Only by exploring optional approaches to a problem can the best solution be found.

5. Independent selection of the level and type of IRAD provides flexibility to exploit promising concepts quickly or as quickly to curtail technical efforts which are not achieving their objectives.

6. If the aerospace industry or any other industry is to remain viable, the price that customers pay for its products must include the cost of keeping current the ability to innovate and compete effectively. IRAD provides this ability in technical areas and is as logical a part of indirect cost as maintenance, administration, depreciation, and insurance.

7. The cost of a contractor's IRAD is allocated to commercial and government work in accordance with accounting policies and practices approved by the government, and cost-sharing agreements between the contractor and government stipulated by the Armed Services Procurement Regulations. As a result, the contractor's commercial business bears its full share of IRAD cost and, in addition, the contractor generally shares part of the IRAD cost allocated to government business.

8. Government agreements as stipulated by the ASPR provide ceilings on the amounts chargeable to the government. The level of IRAD is further constrained by the contractor's need for economy to meet price competition.

In simplest but significant terms, IRAD is a major source of new technology arising from the competitive environment in American industry and the widespread technical competence available in individual companies. Commercial and military products which evolve from IRAD have been and will in the future be a primary factor in enabling the United States to maintain its position relative to foreign competition. In addition to government controls, competition and corporate economics effectively constrain the level of IRAD expenditure and operate to insure its effectiveness.

(Biographical sketch of Mr. Mark E. Kirchner follows:)

MARK E. KIRCHNER

Mr. Mark E. Kirchner became Manager of Boeing-Vertol's V/STOL Transport Branch in September 1969. In that capacity he plans and directs several Vertol V/STOL new business activities.

Born November 23, 1926, in Hampton, Virginia, Mr. Kirchner received his education at the Massachusetts Institute of Technology from 1945 through 1949, receiving both B.S. and M.S. degrees in Aeronautical Engineering from that institution.

Mr. Kirchner joined the Boeing Company in 1949 as an aerodynamicist on the B-47 program. Between that time until 1960 he contributed to many of the Boeing military aircraft production and new business programs with emphasis in the aerodynamics and flight control technologies.

In 1960 Mr. Kirchner became Chief of the Aerodynamics Staff at Boeing's Commercial Airplane Division and, between 1960 and 1964, contributed to the development of the 727 aircraft, the SST, as well as the growth versions of the 707 and 720 transport series.

In 1964 he was transferred to the Vertol Division, located near Philadelphia, as that division's Director of Technology. He then served as Director of Advanced Helicopter Development prior to his present assignment in the V/STOL Transport Branch.

Mr. Kirchner is an Associate Fellow of the A.I.A.A., the Mid-East Vice-President of the American Helicopter Society, member of the Society of Automotive Engineers, and has been active on committees on those societies.

Mr. Kirchner is a licensed commercial pilot, having ratings in fixed wing aircraft, helicopters, and gliders. He also has an instrument rating and actively uses his personal aircraft in his business travels.

Mr. and Mrs. Kirchner are the parents of three children.

STATEMENT OF MARK E. KIRCHNER, MANAGER, V/STOL TRANSPORT BRANCH, VERTOL DIVISION, THE BOEING CO.

Mr. HECHLER. Good morning, Mr. Kirchner.

Mr. KIRCHNER. Good morning, Mr. Chairman. I am certainly honored in being asked to appear before this committee. I have been asked by the Aerospace Industries Association to present to your committee representative views of the aircraft industry on recommendations concerning what NASA should do in the V/STOL field, with emphasis on civil aviation.

The total spectrum of V/STOL: In general, my remarks will encompass the entire spectrum of helicopters, STOL's and V/STOL's. Helicopters have been refined to a relatively high degree during the

last 20-year period and are familiar to us all. Important derivatives of helicopters, such as the winged helicopter and the compound helicopter, are presently in the developmental stage.

STOL aircraft can generally be typified as belonging to one of three categories: first, very low wing loading fixed-wing aircraft; second, winged aircraft with vertical lift augmentation that depend on forward speed for control; third, aircraft with vertical life augmentation that have controls which are independent of forward speed. That is, they have V/STOL-type controls, although they aren't V/STOL aircraft themselves. Although there are STOL types operating that depend on low-wing loading, STOL's which depend on lift augmentation and those with V-type controls are in the same undeveloped status as V/STOL's in general. With regard to (nonhelicopter) V/STOL's, many different types have been proposed, built and flown, but none of the U.S. developments are committed for production, either military or commercial.

Why are no U.S. V/STOL's planned for production? Over the past 15 years this country has had in the order of 20 V/STOL programs for a total cost of several hundred million dollars, and the question is often asked: Why don't we have a product in production? I have two observations with respect to this question which I would like to discuss briefly.

1. The proliferation of configurations.
2. The research rather than prototype nature of the aircraft built.

Let us consider first the proliferation of configurations.

We have studied and built—

Several types using *rotors;*
Several types using propellers; and
Several types using turbofans and jets.

The debate about which type is best has been vigorous and long and has not resulted in firm conclusions at the national level. The debates have been the subjects of numerous meetings, papers, and studies, and have caused frustration to regulatory agencies, Congress, and potential users.

So many configurations have survived so much study because there is no "best" configuration for all considered missions and because in many cases, the differences between configurations are small. The logical selection of an optimum configuration and the simultaneous requirement to define and develop the rest of the total system have resulted in a virtual deadlock of V/STOL developmental progress in the United States—another example of a chicken and the egg situation.

The second observation deals with the nature of the V/STOL programs which have been conducted to date. Most, if not all of them, have been research aircraft and were not prototypes for production and were not configured to be competitive with other transport systems.

There are many reasons why these aircraft were not competitive: lack of the optimum powerplants, no program objective to achieve a competitive payload, low funding level, insufficient technical homework prior to aircraft manufacture.

In summary, we have a paradox: as recent systems studies have shown, there is on one hand increasing pressure to develop short haul V/STOL air transport systems to solve an increasing need. On the

other hand there is frustration over the apparent aimlessness of our V/STOL program and the absence of any emerging operational vehicle.

What is the place of V/STOL in civil aviation? I am certain that we are aware of the ever-increasing difficulties that are being encountered in traveling, especially for relatively short distances. Surface congestion is frequently bumper to bumper—and for the short distance air traveler, the trip to and from the airport in many cases is more time consuming than the flight itself.

Fifty-five percent of the total intercity business travel is under 200 miles. I might say we have emphasized business travel here, because we think it is most applicable to this type of transportation. If you included personal travel, the percentage would be much higher.

Of this, fixed wing scheduled airline penetration is less than 3 percent. However, an airline system that could compete effectively with the automobile and train would find a very lucrative market.

Mr. Hechler. Everybody says the train has been over-competed with so much now, I wonder why we even bother to mention it.

Mr. Kirchner. Well, it is a viable system in the short-haul market and should be considered in the framework in which we are discussing V/STOL transportation, very definitely.

If a V/STOL airline system were sufficiently attractive to capture 10 percent of the business 0–200-mile market, the resulting demand, 1, would be 2½ times the revenue passenger miles generated by the local airlines in 1969, and 2, would require about 275 100-passenger vehicles, a significant statistic.

The Federal Government since 1964 has spent $1.5 million in studies that examined 15 different V/STOL, STOL and VTOL configurations for the short haul market. Three studies were sponsored by NASA, three by the FAA, one by the Department of Commerce, and one by the Presidential Science Advisory Committee. Although each study had its own unique objectives, such as "northeast corridor," a "national short haul system," et cetera, the general results common to most of them were as follows:

One, it was shown by these studies that efficient STOL's, V/STOL's and VTOL's operating from VTOL or STOL sites could compete economically in the proper total system environment with other transportation systems in the short haul market and offered economic and time savings advantages to the users.

Two, the size of the short haul traffic is large and therefore a small shift of this ground traffic to air would be large by air traffic standards.

Three, in addition there are three major environmental problems in establishing a viable short haul air transport system: Noise, air traffic control, and terminal and support facilities.

All of this results in a major quandary. The traffic appears to be available, but the size of the vehicle to be economically viable approaches 100 passengers and therefore represents a major developmental cost. Finally, the traffic, ground facility, and community acceptance problems are so complex that any airframe development alone is doomed to economic failure unless these problems are simultaneously solved.

Mr. Hechler. Excuse me. I would think community acceptance would be more difficult with your larger aircraft.

Mr. KIRCHNER. The community acceptance problem is difficult because the benefit of a V/STOL transportation system necessarily places the terminal facilities close to the communities, and therefore you get into all of the problems associated with a local community.

Mr. HECHLER. What I was trying to drive at is that most communities would rather have a V/STOL facility than a large jet facility at their doorstep, wouldn't they?

Mr. KIRCHNER. They are different communities. The communities near Kennedy have already expressed objections to the interference to their daily lives by the Kennedy-type facility. If V/STOL facilities were provided they would obviously be spread out and be at new locations, and you would have new community problems associated with them.

Mr. HECHLER. It is a matter of degree, though.

Mr. KIRCHNER. It is a matter of degree. It is a very serious problem, though. Take New York City alone, Manhattan Island. There was a Pan American Building operation, and it had community problems, from the question of safety, the question of noise, and so on.

Now, of course, we are going to address those problems more, and we hope we are working successfully on them. But they are problems, and they are associated with the community acceptance.

There are considerations of building a STOL port on Manhattan Island and at other locations. There are other vertiports proposed for Manhattan also. Each poses individual community problems. Oscar Bakke of the FAA considers this the main stumbling block of the whole V/STOL development.

And for that reason he is expending a good deal of his energies on that. I may be quoting him incorrectly, but I hope not. He feels that, unless we can identify in the next 8 years real estate which can be dedicated toward air traffic corridors and be associated with them, it will be too late. It might be impossible to do so thereafter, because of the increasing commitments for other purposes of certain land dock space, and other space that might be used for this purpose.

Mr. HECHLER. That is a very pertinent observation.

Mr. KIRCHNER. Let's observe how we stand relative to Europe. Let's summarize recent European progress to help add perspective to this question.

Progress in the United Kingdom on VTOL has followed a consistent line of development—mainly toward jet lift. The Hawker-Siddeley Harrier is the only production V/STOL aircraft in the Western World. It is now in service with the Royal Air Force and is being evaluated by the U.S. Marine Corps. This aircraft is a development of the Hawker-Siddeley P–1127 which first flew in 1960.

The British Ministry of Technology is at present considering final proposals in an industry competition for research and development funding on civil VTOL projects. A Ministry decision is expected to be made in December 1969, and involves a Hawker-Siddeley 16 lift-engine transport, a British Aircraft Corp. STOL design, and Westland tilt-wing and tilt-rotor concepts.

It is interesting to note two facts here: First, the British have intensively studied and promoted the use of lift engines, and secured collaborative agreements with the French and Germans; this R. & D. investment may influence the British choice of concept. Second, the

British Ministry of Technology evidently considers that short-haul V/STOL air transport will be competitive with an already well-developed surface transport system.

West Germany, in an attempt to leapfrog to a position of competitive strength, has decided to concentrate most of their aeronautical research and development in one area—V/STOL. Two VTOL designs have been built and flown; these are the EWR VJ-101 jet-lift fighter and the Dornier 31 jet-lift transport. Another VTOL fighter type, the VAK-191B, is due to fly in the next few months.

The present center of West German commercial V/STOL interest is the joint Luftwaffe/Lufthansa Study, controlled by the German Defense Ministry, for a V/STOL short haul, transport sized to carry 100 passengers. This is very similar to the British study. Submissions have been made as follows:

VFW VC-400/500 tandem tilt wing.
VFW VC-180 jet-lift transport.
VFW VC-181 jet-lift transport.
MBB Boelkow 140 tilt wing.
HFB HFB-600 jet-lift transport.
Dornier DO-231 jet-lift transport.

Gross weights of these projects are all in the 100,000- to 120,000-pound category. That is the gross weight of the machine.

The French developed the Breguet 941 deflected slipstream STOL transport aircraft. McDonnell-Douglas is the U.S. licensee and operational experiments have been conducted by Eastern and American Airlines.

Apart from the De Havilland of Canada series of low-wing-loading STOL aircraft, the main Canadian V/STOL effort has been conducted by Canadair with the CL-84 tilt-wing aircraft. Two years of flight testing a prototype between 1965 and 1967 led to an order for three more CL-84's for evaluation by the Canadian armed forces. These three aircraft are due to fly in 1970.

There are no active V/STOL developments in this country comparable to those outlined above in either the commercial or military areas. This country has no program comparable to Germany or England to identify a specific V/STOL for configuration production prototype development.

The requirements for a system approach: Last year, Dr. Stever, Chairman, Aeronautical and Space Engineering Board, National Academy of Engineering, presented to this committee a report as a result of a year's study entitled "Civil Aviation Research and Development: An Assessment of Federal Government Involvement." He stated that their most important recommendation was that the Federal Government take a stronger role in R. & D. for civil aviation. We concur with this as a major recommendation and believe that his recommendation which covered all civil aviation is particularly applicable, and even more important, to V/STOL's and STOL's.

I would like to discuss Dr. Stever's recommendations in the following three areas:

1. Total system requirements and analysis;
2. Vehicle development;
3. Technology R. & D.

Total system requirements: With regard to total system requirements and analysis, Dr. Stever's study recommended that the newly

established Department of Transportation was the natural agency to coordinate the Federal Government's effort to define the needs and make the recommendations for a national program.

His report stated that—

> Goals should be formulated with reference to the nation's total transportation system, taking account of the increasing public demand for air transportation as well as the various economical factors that bear on civil aviation. Although an in-house Government capability should be developed and maintained by DOT in transportation systems anaslyis, it is strongly recommended that industry and other private institutions participate in carrying out these studies.

We are very pleased that this recommendation has been implemented with the establishment of the joint DOT–NASA civil aviation R. & D. policy study whose executive director is Lawrence P. Greene. The objective is to define total system requirements, aviation requirements, and R. & D. policy recommendations by the end of 1970.

Vehicle development: In the case of the V/STOL and STOL fields there are many configuration options so that the process of selecting the correct ones to optimize for production is a formidable task. As indicated earlier, Germany and England recognize this problem and have programs to select a single configuration for the development of prototype vehicles and related technology.

In order to focus technology research and vehicle development in this complex V/STOL field, it is recommended that NASA continue to contribute to the system studies being directed by DOT with respect to the technological aspects. The airlines in their role as ultimate user must be active participants in developing the system requirements including vehicle technical requirements.

The adherents of various concepts should participate in the studies to insure that the good decisions are reached. Funded industry participation with sufficient depth will allow technical consistency and provide substantiation in areas such as structures, weights, propulsions, control, et cetera. The results from these studies will be valuable in highlighting the technological research areas that need emphasis.

Mr. HECHLER. Excuse me, Mr. Kirchner. A brief interjection here. The comments you are making with respect to STOL and V/STOL could well apply to other areas across the board, could they not, sir?

Mr. KIRCHNER. Yes, to some extent. We do believe they are particularly important to V/STOL and STOL, because of the requirement to develop the total system simultaneously with vehicle development.

In other words, with fixed-wing aircraft and our conventional aircraft system, we do have an existing system. The manufacturer can go out and develop a new aircraft on his own, and know that the system exists ready to receive that aircraft. So it is the quality of the aircraft that is going to determine whether it can be useful or not. Not so with STOL or V/STOL, because if you develop a V/STOL or STOL aircraft independently without the rest of the system being developed it can't compete in the present environment. The environment for a competitive system doesn't exist.

The conventional aircrafts are better on our conventional airports and conventional airways systems.

Mr. HECHLER. Thank you.

Mr. KIRCHNER. Technology R. & D. The traditional leading role of the NASA in aeronautical research should be reestablished. Facilities required for this research need major improvement and are dis-

cussed in a following section. An appendix attached to this testimony details the compilation of industry recommendations for technology research of importance to the V/STOL field. Next I would like to cover highlights excerpted from that compilation.

Research and development highlights. I would like to interject a statement here relative to the discussion that took place with Mr. Perkins. That has to do with some of the research areas that we do not discuss in our compilation.

They involve the development of the electronic support equipment for collision avoidance, air traffic control, operational problems and so on, as pertinent to the previous discussion.

We support research in these areas. We support NASA's Electronic Research Center and the contributions it is making to these areas. The reason we left them out was that we are aware that the FAA and NASA are trying to work out their relative roles in these areas and, as Mr. Perkins said, we do not want to appear to have an ax to grind with respect to which of the two agencies is prime.

We do support the development of that research. We don't want to appear not to. But we do not know, and frankly do not care, who in the Government manages it.

Mr. HECHLER. Just so long as it is managed.

Mr. KIRCHNER. So long as it is managed. So we beg for a decision, and we will cooperate with that decision.

Mr. HECHLER. I appreciate your clarifying that. That is very helpful.

Mr. KIRCHNER. Likewise, you will see in my testimony that I do not make specific references to electronic support equipment and operational problems, other than specifically those areas where we do believe it is clear that NASA is prime.

As you will see, many of the separate discipline or technology items mentioned by Mr. Perkins in his testimony are of great importance for the V/STOL field also. Additional areas of unique importance to the V/STOL field can also be identified. While some of these areas are applicable to all types of V/STOL, others are strongly related to specific configurations, further emphasizing the need for focusing our activities to prevent dilution of technical research. Among the areas applicable to all types of V/STOL, the following are of primary importance.

1. *Terminal area operations.*—The pay-off of V/STOL aircraft is critically dependent on avoiding the terminal area congestion experienced by conventional fixed-wing aircraft. Advantage must be taken of the low-speed, steep-angle capabilities of these aircraft to develop a terminal area operating system providing rapid landing, turnaround, and takeoff.

NASA should work on improving the technical characteristics of aircraft for terminal area operations.

2. *Materials.*—Advanced materials, particularly composites, are rapidly coming into use for special applications. Structural design concepts which are matched to these materials need to be developed to reap maximum benefits. This is especially true for rotors and propellers where the cascading effect is such that, for a given mission, each pound of weight saved can reduce the vehicle gross weight by as much as 6 pounds.

3. *Flying qualities and flight controls.*—Civil flying qualities specifications are the responsibility of FAA. NASA should contribute to

the technical development of the V/STOL specifications by appropriate analysis, simulation, and flight research. Research on fly-by-wire systems specifically adapted for V/STOL's is important.

4. *Advanced propulsion systems.*—Special efforts should be pursued to raise the allowable turbine inlet temperatures permitting a reduction in engine weight and in fuel consumption. Advanced materials are required to permit these temperature increases.

In the following areas the work required is critically dependent on the configuration selected.

NOISE

Noise reduction is required for rotors, propellers, and engines, yet improved vehicle performance seems to promote designs which produce high noise levels. We need noise research in all areas, but we must not neglect the special problems of rotor, propeller, or jet-driven V/STOL configurations.

AERODYNAMICS

Interference effects between wings and bodies and the powered lifting system (rotors, propellers or jets) are especially important for V/STOL aircraft. These effects need to be carefully studied in the wind tunnel and analytically. Ground proximity effects are also important. These effects include downwash, reingestion, recirculation, and "suck down" effects, and critical areas for research vary substantially between rotor, propeller and jet-driven configurations.

FLUTTER AND DYNAMIC STABILITY

The configuration of many V/STOL designs makes them particularly susceptible to various combined rotor-airframe dynamic flutter phenomena. Efficient and reliable means to predict and control these phenomena must be developed and verified by test.

ANTICIPATED FACILITIES REQUIREMENTS

V/STOL technical research presents problems which demand certain specialized facilities which are not necessary for conventional aircraft. In wind tunnel testing the large masses and high velocities of airflow used to generate powered augmented lift can disturb the tunnel flow and reflect from tunnel walls.

This suggests that much more work needs to be done in tunnel testing techniques to obtain good data in conventional wind tunnels and that special purpose test facilities must be created. Moreover, the ground effects resulting from the impingement of the slipstream on the ground presents problems on all V/STOL configurations which require far more investigation.

Large wind tunnels with good low-speed characteristics and equipped to simulate low-speed operation, particularly near the ground, and to simulate the effect of gusts, are urgently needed for the quickest and most effective development of all V/STOL configurations.

Flying qualities of V/STOL's, especially at low speeds, and steep flight paths are vital to the critical terminal operations. Most configurations offer opportunities for developing both stability and control characteristics which can be optimized to minimize pilot tasks and maximize aircraft safety in these low-speed regimes.

Proper optimization of these stability and control characteristics requires good simulation. Specifically, large amplitude moving base simulator facilities are required which would satisfy the total spectrum of V/STOL flight from hover to cruise.

Noise will be a controlling factor in the operational usage of V/STOL's in the downtown areas where the characteristics can provide a maximum commercial benefit. Modern acoustical research and measurement laboratory facilities including an acoustical wind tunnel need to be provided.

NASA could make a major contribution to the rapid and effective development of V/STOL aircraft by providing these facilities.

I would like to interject another comment here if I might. We discussed in Mr. Perkin's testimony the question as to whether the Government should provide, for the benefit of industry, facilities—research facilities.

And I think the answer to that involves a matter of degree. It is a relative thing.

I would like to point out that I am just an expert in the Boeing operation, but Boeing is only one of the many companies we are representing here, and Boeing alone has built its own $8 million V/STOL wind tunnel facility and it is full with our own research.

Now, not to stay NASA hasn't done so, too. They have built a wind tunnel similar to ours. I might say quickly others in industry have done the same thing—Lockheed has a tunnel similar to ours, and I am sure there are other companies that have other advanced facilities for V/STOL. Also, NASA has done the same thing.

But their tunnel, to support the whole country, is no more sophisticated than ours. One might mention the vertical wind tunnel that NASA has built. It is not really a vertical wind tunnel. It is a hover chamber, in which you can test rotors and other smiliar devices.

I would like to refer to the level of money spent on V/STOL research. I know that NASA's numbers are somewhat argumentative; because of bookkeeping problems, it is hard to figure out what is clearly applicable to V/STOL. You will see that we quote that NASA spent $8 million for V/STOL research in fiscal year 1969. Now, I don't have the figures on all of industry, but Boeing alone, in our own small division, spent approximately twice that much in calendar 1969.

So it is a matter of degree. We look to the Government for leadership in what they want.

And of course NASA is one of their tools. Industry certainly uses the level of Government interest as one of the important indicators in establishing its research levels in various areas.

I would like to submit for the record an appendix listing required V/STOL research.

APPENDIX

Appendix to Testimony of M. E. Kirchner

Detailed Listing of Significant Technology Elements for NASA Research on V/STOL as Compiled from Industry Recommendations

Propulsion

- Reingestion problems of direct lift engines.
- Factors affecting lift engine reliability.
- High tip speed fans and compressors (1600–1800 fps).

Increased turbine inlet temperatures (3000–3200° F).

This requires work in cooling systems and high temperature materials.

Improved materials and processes. Boron and graphite in resin and metal matrices and high strength nickel super alloys offer promise.

Improved engine/aircraft integration. Benefits include drag reduction, maintainability and lower weight.

Improved tolerance to inlet flow distortion.

Criteria for lift engine in-flight starting.

Large diameter V/STOL propellers.

Technology of cyclic pitch applied to V/STOL propellers.

Airfoils for V/STOL propellers.

Structural design and loads criteria for V/STOL propellers.

Human factors

Integrated display and cockpit design.

Materials

Properties of composite materials and systematic investigation of a variety of structural concepts suited to these materials.

Fatigue data in both low cycle and high cycle ends of the spectrum for advanced materials.

Rotary wing aerodynamics

Airfoil dynamic and aerodynamic data in reverse flow, stall and oscillatory angle of attack environments typical of helicopters.

Jet flap and circulation controlled rotors, both gas driven and shaft driven.

Aerodynamics of slowed, stopped rotors.

Rotor and propeller dynamics

Analytical methods to predict and control prop/rotor/airframe dynamic instabilities. Obtain test correlation.

Noise

Noise attenuation for direct lift engines.

Noise attenuation for propellers and rotors.

Acoustic fatigue criteria for direct lift engines and associated structure.

Stability and control

Flight control requirements for IFR operation in confined areas such as roof top VTOL or STOL ports.

Control power criteria for V/STOL vehicles.

Fly-by-wire control system design criteria for V/STOL vehicles.

Cross wind effects on various V/STOL and STOL configurations.

Flying qualities requirements for very large rotary wing aircraft.

Flight management systems including power management and automatic stabilization and control.

Steep descent rate stabilization system.

Aerodynamics

Externally blown flaps and other high lift devices in conjunction with direct lift engines for VTOL and STOL aircraft.

Downwash effects of propeller, fan and jet lift systems.

Aerodynamic ground effects.

Interference effects between direct lift engine and various high lift devices.

Mr. HECHLER. Would aerospace industries be able to supply a figure for total industrywide effort?

Mr. KIRCHNER. We will attempt to provide for the record at a later date a compilation of R. & D. conducted by industry on V/STOL in 1969.

Mr. HECHLER. I would appreciate that.

Mr. KIRCHNER. All right.

So it is a matter of degree, you see—it is a relative thing. We appreciate what the Government does for the country, but we look to the Government for leadership. We have discretionary funds we can direct toward one thing or another, and we are all searching for what is good

for the country. What is good for the country is good for us too, and we want to build the products the country wants.

In summarization, in describing our recommendations for NASA's V/STOL research program, I have discussed the following topics:

(*a*) The status of the U.S. and foreign V/STOL programs.

(*b*) The establishment of the joint DOT–NASA civil aviation R. & D. policy study.

(*c*) The suggestion for NASA to participate with industry in the DOT systems studies in order to formulate expanded V/STOL research programs.

(*d*) A suggested list of specific research and developments items.

(*e*) Recommendations for increased NASA facilities.

The urgent work for NASA that we have recommended would require a substantial increase in NASA's aeronautical research funds devoted to V/STOL, compared to the approximately $8 million they had in fiscal year 1969—only 0.2 percent of the total NASA budget for that year.

Thank you.

Mr. HECHLER. Thank you very much, Mr. Kirchner.

Mr. Goldwater, do you have any questions you would like to pose?

Mr. GOLDWATER. I want to ask a few, Mr. Chairman.

This area of V/STOL, vertical lift, is, I guess, in a way, not new, but it is new in the sense we don't have them flying around.

Mr. KIRCHNER. That is correct.

Mr. GOLDWATER. In your work, what system do you have? That U.S. industry has come up with what seems to be the best system so far, or can you really say?

Mr. KIRCHNER. It is difficult to comment on that. Various members of the industry do have different approaches. Of course, I believe, they have different degrees of substantiation.

I do believe that is an area where NASA can help. The DOT–NASA study group could establish which ones, through the substantiation that has been produced, might enjoy or deserve further work.

I can only say that there are several.

Let me enumerate the kinds that are typical. With regard to STOL's we have propeller STOL's such as the McDonnell-Douglas Breguet derivatives, which are essentially high-lift fixed-wing aircraft with turboprops.

Now, an extension of that concept is to put a hinge on the wing, allow the wing to tilt, and you have what is called a tilt-wing aircraft. This aircraft can actually slow down to zero speed and go to a full hover in flight.

Other types of STOL's are fan STOL's. Now, fan STOL's do not depend on propeller slipstreams over the wing in order to provide augmented lift, but there are ways of providing augmented lift on such designs. Blowing the fan exhaust air over external flaps (called externally blown flaps), bleeding the engines and providing boundary-layer-control or jet-flap action, are samples of this type of augmented lift.

We would call those augmented STOL's. The best example I can think of is the Boeing 707 prototype which was modified to have boundary-layer-control flaps. It was actually flown by NASA in that configuration, as a matter of fact. There are none that I can think

of right off hand that you might be more familiar with than that particular one.

Going on, in the V/STOL area, we have the familiar vertical lift engine configuration where vertical lift engines are either placed in the fuselage, in wingtip pods, or in some kind of retractable configuration, such that they provide augmented vertical lift to the wing lift. This approach can be used as a STOL where the lift-engines don't provide enough lift to lift the entire weight of the aircraft, or a VTOL aircraft, in which case they do.

Another configuration can be described as a tilt rotor. A tilt rotor is similar to a helicopter, in that it has rotors to provide the main lift. But for forward flight, the aircraft converts by tilting forward these rotors to a horizontal position so they look like very large propellers. This is a V/STOL machine.

There is the compound helicopter. The difference between a winged helicopter and a compound helicopter is that a compound helicopter has not only a wing but an auxiliary forward propulsion system in addition to the wing.

The vertical rotor of the compound helicopter is used only for lift. In the winged helicopter, the rotor is not only used for vertical lift but is tilted slightly forward to provide the propulsive force in cruise.

I would say that generally covers the scope of the types of configurations that are most common. I apologize for leaving out any which I haven't thought of at the moment.

My point is that we have a variety of these options that I have described. That is one of the problems. They are sophisticated machines. Any one of them requires substantial research.

So when we have the total spectrum in front of us it is difficult to see how we can expect NASA to do research on everything. We don't expect them to.

That is why we recommend that the study group try to focus, as a result of the work that has already been done, upon fewer, more substantiated configurations of those that have been studied, so industry as a whole can work on those in a more concentrated way.

Mr. GOLDWATER. What you are saying now is that the art is not refined at all, it is sort of in a broken stage.

Mr. KIRCHNER. I would say it is somewhat refined, but there are too many options. The work that needs to be done is largely developmental. I think the invention aspects of the technology is fairly well in hand.

The developmental aspects of the technology is not as well in hand. That is the important point. That is why one would like to focus one's attention on the developmental research of a fewer number of options and make more substantial progress on those.

Which ones you would concentrate on are largely a function of the analysis of the total system requirement. In many cases the configurations are not only different technically but they are better at slightly different applications.

Mr. GOLDWATER. Would your answer be that NASA take the leadership?

Mr. KIRCHNER. Well, I was asking for the DOT-NASA study group take the leadership in this kind of systems work, and for NASA to

take the leadership in supporting that kind of activity from a technological standpoint.

Mr. GOLDWATER. It seems to me industry would be probably a better judge of it.

Mr. KIRCHNER. We certainly want industry to participate. We also want the airlines to participate.

We think leadership is required with regard to the focusing task, and I don't want to imply for a minute that we think industry should be excluded from this. We think industry should in fact do most of the work in support of this activity, particularly on a funded basis. When it is on a funded basis, it is in a competitive environment, and you get the best work done.

But you see, since the total system involves so many elements that industry has no control over, the Government can contribute from a management standpoint. It all has to be done in an organized way. Industry could do more if the vehicle development were the only problem. But since it isn't, industry can't.

Mr. GOLDWATER. Thank you.

Mr. HECHLER. This goes back to what Mr. Anders said the first day, this is also a people problem, as well as a technical problem.

Mr. KIRCHNER. It certainly is.

Mr. HECHLER. I wonder what some of the other inhibiting factors are.

You mentioned the great argument that is going on. Is this a technological argument entirely?

Mr. KIRCHNER. Well, not entirely—certainly not entirely. I think the main inhibiting factor is a lack of the national objective of what we want to do in this country.

Mr. HECHLER. This national objective, of course, relates not only to the decision which is technical, technological in nature, but it relates to a decision concerning the whole transportation system?

Mr. KIRCHNER. Exactly—exactly.

Mr. HECHLER. The size of airports?

Mr. KIRCHNER. Exactly.

Mr. HECHLER. The community acceptance problems which you mentioned?

Mr. KIRCHNER. Exactly.

You see, if goals and objectives were established, the various governmental agencies would have something to hang their hat on, to proceed, in support of those objectives. In doing so, they might provide the environment with which industry could then come in and independently develop and suggest to the airline customers a vehicle which will be compatible with whatever system, total system, was being supported.

Now, in the event the various total system elements were not produced in a timely fashion, even though the total system national goals and objectives were identified, it might require some Government-sponsored program in the vehicle development area to satisfy those national objectives such as has been done in the SST program—but for different reasons than the SST program.

The SST program posed a financial resource problem. In the V/STOL program we have a total system development problem, an entirely different reason.

Mr. HECHLER. I might say I concur completely with what you say, and I think a simple statement of the national policy would contribute materially to breaking this great bottleneck that we have on V/STOL's.

Just to cite one example, there are many sections of the country that is puzzling over what kinds of airports to develop.

Mr. KIRCHNER. That is right.

Mr. HECHLER. Even when they come to the conclusion they are going to need a certain size airport, and the FAA agrees to it, somebody is sure to come along and say V/STOL is going to be developed next year, so you might just as well forget your 8,500-foot runways.

This is a very, very difficult thing for people in communities where you have to make these decisions and vote in bond elections. It is an extremely difficult decision to arrive at in the absence of such a national policy.

Mr. PERKINS. Mr. Chairman, may I contribute to this?

We had considerable discussion yesterday on this very frustrating subject. This is a conclusion that I came to personally. I don't know how much the rest of the industry might subscribe to, but I thought it might be helpful to read this to you.

It has so far not been economically feasible to introduce STOL aircraft or V/STOL aircraft into general commercial use, because to do so would require that each of the following five conditions be met. And I have five conditions I have listed. I emphasize the word "each."

1. If it is a STOL—and a similar limitation applies to V/STOL—it must be large enough and efficient enough to be economically viable in airline use. Otherwise the airlines won't buy it.

2. The number of aircraft of a given model—I emphasize a given model—which a manufacturer can count on selling, must be enough to make the program feasible from the manufacturer's viewpoint, so that he can break even at least on his development and startup costs. Otherwise the manufacturer won't built it.

3. Air traffic controls must be available to make it feasible to operate these aircraft as well as other aircraft in many cases on the same airways and the same airports.

4. Airports and supporting facilities, with adequate environmental conditions, to permit efficient operations of these type aircraft must be provided.

5. FAA certification and operating requirements must be determined in advance—and I emphasize the word "advance"—so that manufacturers and airline operators can proceed with some confidence in developing the aircraft and providing for its operation. Currently the requirements for such a machine are not established. As far as I see there is no intention to establish them until after the aircraft is developed, which is too late.

Mr. HECHLER. Can't you get even more specific in some of your points, by indicating that V/STOL can have its primary use in highly populated short-haul situations?

Mr. PERKINS. That would be the general best application I should think, yes.

Mr. HECHLER. That would lead you one step closer to a conclusion.

Mr. PERKINS. It is difficult to see how all these things can be met, but one possible solution, and I emphasize "possible," is:

First, a well-planned, well-managed and well-funded national program to provide the necessary traffic control system and the airport facilities. This might well be a function of DOT.

Second, a well-planned and funded national program for the development of one or more such aircraft—and I here emphasize "one or more," because I suspect at least one V/STOL and one STOL would need to be developed—of appropriate size and meeting airline requirements. This, parenthetically might well be most feasibly carried out in conjunction with DOD, as I referred to in my statement.

Third, NASA support of the above efforts from a technical standpoint.

Fourth, the FAA determination of its certification and operating requirements in advance.

Mr. HECHLER. Do you have anything further to add?

Mr. KIRCHNER. No, I do not, sir.

Mr. GOLDWATER. Mr. Chairman, I would like to ask one question.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. I think it is well pointed out in the overall plan and design—I think we are well aware of the need—that this need seems to become more pointed, and is becoming more pointed every day. Perhaps there is need for an overall plan so that industry can be pointed in the right direction and they can tackle this problem.

But short of the facts there doesn't seem to be apparently any overall plan. Industry is continuing to meet this need—and won't it continue this development, even though there is no Federal program.

I think the industry is well aware of where the need is.

Mr. KIRCHNER. Industry can't meet the need. I think my comparison between what is going on in Europe and what is going on in the United States has indicated we are not meeting the need. We can't possibly meet the need. Mr. Perkins remarked that we can't develop a vehicle without certain conditions existing—and they don't exist—or else the program would experience economic failure.

Now, all is not lost. The Government does have a mechanism that they have taken the trouble to establish to work out this problem. This is the joint DOT–NASA group, and I might add that others are participating in their studies, including DOD from a military standpoint, and industry and the airlines are also being asked to participate as required.

We urge that you pay attention to the recommendations of this group. We don't necessarily believe you have to follow the recommendations, but we think the Government should consider them and then make judgment as a result of considering them, one way or the other, and set aside some goals and objectives as a result of that.

Now the group has a timetable, and they hope to have some progress in 1970.

We recommend to the Government that they use the groups that have been established for this purpose, and then make judgments as a result of the work.

We hope that will give us all guidance, and I think maybe this will be a useful mechanism if we all recognize and use it. If it is ignored, the group will not have been useful.

Mr. GOLDWATER. You will continue?

Mr. KIRCHNER. We will continue to have a completely unsatisfactory V/STOL technological situation in this country.

Mr. GOLDWATER. There is a commercial advantage, the profit motive.

Mr. KIRCHNER. Only in the proper environment. I must qualify it that way. The proper environment does not exist.

Mr. GOLDWATER. Do you think it ever will?

Mr. KIRCHNER. I think it can if there is leadership to identify goals for us all to look to; unified objectives to which the various agencies—NASA, local governments, FAA, and so forth—all can look to as a guide so they can make independent decisions in a way that support that objective. Yes, we can develop the environment.

Mr. PERKINS. I would like to inject the death rate of companies working solely on V/STOL and STOL has been unusually high.

Mr. HECHLER. Is there anything further, Mr. Goldwater?

Mr. GOLDWATER. I don't think so.

Mr. HECHLER. I would like also to recognize the presence in the hearing room of the legislative counsel for Aerospace Industries, Lloyd Kuhn, who has been very helpful to the committee.

There are many other areas that this committee would like to keep you here to inquire about, but obviously the time doesn't allow us to do so. We would encourage you to submit any other material for the record on the subjects that we have raised this morning.

The committee is holding these hearings for the purpose of focusing attention on the need for development of the various things that you have recommended, and we appreciate very much, Mr. Perkins and Mr. Kirchner, your appearing here this morning.

As there is no further business before the committee, we will stand adjourned until Monday at 10 a.m.

(Whereupon, at 12:06 p.m., the committee was adjourned, to reconvene on Monday, December 8, 1969, at 10 a.m.)

AERONAUTICAL RESEARCH

MONDAY, DECEMBER 8, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 2325, Rayburn House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The committee will be in order.

We are very pleased to welcome back to the committee Dr. Thomas O. Paine, Administrator of the National Aeronautics and Space Administration.

Dr. Paine, we were pleased and honored last year that you could lead off our hearings on aeronautical research, and we are honored again to have you back this year.

Do you have a prepared opening statement that you would care to offer the committee?

Dr. PAINE. Yes; I have a short statement, Mr. Chairman, and then I will be very happy to answer any questions which you may have.

STATEMENT OF DR. THOMAS O. PAINE, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. PAINE. Mr. Chairman and members of the subcommittee:

NASA welcomes these important hearings on Aeronautical Research and Development and appreciates the opportunity to participate in them.

These hearings and those held by the subcommittee last fall have served to focus national attention on the problems facing us in civil aviation. They have also provided a stimulus to efforts in planning and implementing a systematic approach to future research and development programs in aeronautics, as they involve NASA, other Government agencies, and industry.

We at NASA fully appreciate the role that the Committee on Science and Astronautics has consistently played in emphasizing the need for farsighted programs in aeronautical research and development. The committee and particularly this subcommittee have been a moving force in gaining support for the steady increase in funding within NASA for aeronautics over the last few years.

Last fall when I appeared before the subcommittee I pointed out that because of major changes which have occurred in the past decade, there is a pressing need to define the direction and pace in this Nation's aeronautical research and development efforts. Inherent in defining our

national goals and setting priorities is the question of determining the proper role of the Federal Government in fostering advances in civil aviation transportation systems. It is clear that future advances in aeronautics must complement the Nation's overall transportation systems within constraints imposed by urban environments. It is also clear that advances in ground-based systems serving civil aviation, such as airport facilities and air traffic control systems, must be stressed so as to keep pace with advances in aircraft. Also, in gauging the importance of aeronautical research and development, we must be continually mindful of the significant contributions of U.S. aerospace exports to our balance-of-trade position and the growing challenges to this country's leadership position in the world's aerospace markets.

As you know, since your hearings last year, NASA and DOT have undertaken a joint study on civil aviation research and development policy, and we are now actively engaged with DOT in working group sessions. This study, and the opportunities it presents for closer coordination between NASA and DOT at the working level, will help us to establish more precisely than in the past, goals and priorities within the Government to stimulate the development of advanced aircraft transportation systems.

We are also jointly studying with FAA and the Coast Guard the feasibility and requirements for satellite systems to provide navigation, communications and surveillance services for aircraft and ships. Such satellite systems could greatly improve our capability for over-ocean air traffic control and aircraft and ship telecommunications, both voice and data, to shore as well as navigation and collision avoidance.

An example of our efforts to strengthen our close working relationship with the DOD in aeronautical research and development is the recent agreement with the Army Materiel Command providing for the utilization of AMC personnel of test chambers, wind tunnels and other facilities at the Ames, Langley, and Lewis Research Centers. Under this new agreement current efforts by AMC at the Ames Research Center will be expanded and joint projects at the Langley and Lewis Research Centers will be undertaken. These efforts will relate primarily to the Army's low-speed aviation research program. It is presently planned that approximately 175 Army military and civilian personnel will be assigned to the three NASA sites in fiscal year 1970.

Accompanying me today is Mr. Charles W. Harper, Deputy Associate Administrator (Aeronautics) for Advanced Research and Technology, who will comment on the testimony presented thus far in these hearings in the context of NASA views of the challenge we face and our efforts to meet these challenges.

Mr. Chairman, as I said at the outset, we welcome these hearings. I am sure they will provide us with a deeper understanding of the complex task of tailoring NASA's research and development actions in aeronautics to this Nation's needs in the decade ahead.

Mr. Chairman, this concludes my statement.

Mr. HECHLER. Thank you, Dr. Paine.

I have expressed at these hearings the need for the formulation and definition of national goals and priorities and a national aviation policy. I think this is a critical need at the present time. Much research in aeronautics I think has been hampered and delayed by the inability to ascertain what the goals and priorities are.

You have indicated in your testimony the fact the DOT–NASA group is working in this general direction.

Dr. PAINE. Yes.

Mr. HECHLER. I am inclined to feel that we won't make any progress and we won't have clear leadership in this field until national aviation policy is expressed at the highest level, namely, the presidential level.

I wonder if you would care to make any comment on this?

Dr. PAINE. I think what we are seeing here, Mr. Chairman, is the fact that increasingly the R. & D. in aeronautics that is carried out must reflect a broader systems understanding. We are past the era where the NACA engine cowling, for example, which relates to a specific technological subsystem, is enough of an advancement. We need much more clearly to understand the entire transportation system of the Nation and the degree to which the aeronautics components of this fits in. Within the aeronautics component we need to understand much more fully the way in which the airframe, the propulsion system and the structure and the other parts that actually fly are integrated with the ground system, with the air traffic control systems, and indeed with the metropolitan transport systems within which these interact.

So it is very important that as we consider the question of the future R. & D. in aeronautics which the National Aeronautics and Space Administration will carry out, we do so in concert with the Department of Transportation in respect to the civil area, just as we have in the past worked out some very excellent relationships with the Department of Defense in respect to the military activity.

The real significance of the DOT–NASA study is the fact that it does represent the first and a major effort to get these things together.

Now we also of course are working to help the National Aeronautics and Space Council to take a broader view in the aeronautics area. I believe in the testimony of William Anders before the subcommittee earlier he pointed out his desire to do this, and we are cooperating in every way with the Council; which I think is another way of achieving this new broader, higher level interest of which you speak.

Mr. HECHLER. I am not in any way trying to downgrade the DOT–NASA study. I think it has done the very helpful things you pointed out. All I am saying is that when national policy comes up from below, sometimes it doesn't state as clearly and sharply the types of goals and priorities which are badly needed in order to make progress in the field of aeronautics. I would certainly hope that this expression could come from the highest level and not necessarily reflect simply the lowest common denominator agreement at the lower working level.

I would hope also that it deals with forecasting planning and requirements in terms of the need of the Nation rather than merely tailoring the research to the availability of particular facilities or personnel, vehicles, or points of view. I would like to get your reaction to this point also.

Dr. PAINE. Yes; I think this is absolutely essential. The progress that we are making now in this joint study is very much along these lines, of defining necessary needs and defining the opportunities that we have in the context of the total transportation system as well as in the context of the R. & D. environment and the opportunities we see in the technological side. That is the real importance of this study—the fact that we are bringing these together.

Mr. HECHLER. As you know, I expressed great disappointment that the space task group did not deal with aeronautics in its report.

Dr. PAINE. Yes.

Mr. HECHLER. Do you think there ought to be an aeronautics task group that focuses attention on the need for aeronautical research and development?

Dr. PAINE. In the very first meeting of the space task group we raised the question of whether we should indeed include aeronautics, Mr. Chairman, and it was the decision at that time that, because of the very short time before the first scheduled attempt to land on the moon and the fact that the administration would have to make its space decisions on a very tight timetable, in the interest of time it would be best to exclude the aeronautics area from the space task group consideration and for that particular group to concentrate on the space program.

The fact that we now have that part of our task behind us raises the question perhaps as to whether or not a similar effort in aeronautics is required. It is not clear to me that we face the same problem there, particularly I think with the coordination we have between NASA and DOD with the AACB, between NASA and DOT, and the other relationships we have been able to establish, for example, with respect to the question of noise pollution. In these special working groups, which include the Department of Housing and Urban Development, I think we have more satisfactory mechanisms in the aeronautics area than we had in the space area at the time we set up the space task group. But this is certainly something that we ought to look at.

Mr. HECHLER. You may recall last year the opening question I asked at the hearings was what the Soviet Union was doing in the area of aeronautics. Do you have any further report this year as to the extent of emphasis that the Soviet Union is placing on aeronautics as related to space?

Dr. PAINE. I think it is fair to say that the past 12 months have seen the United States demonstrate to the entire world in the area of space a very advanced capability. And at the same time we have seen the Soviets continue to have some difficulties with their program. Therefore, I think that in the space area it is clear that the United States has certainly regained the lead that the Apollo program was specifically designed to regain.

In the aeronautics area on the other hand, the situation is by no means one of demonstrated continuing American superiority. Here we see a very intensive effort on the part of the Soviet Union to develop and fly experimental aircraft with very advanced capabilities. The Soviets of course were the first to fly a supersonic transport prototype. The Soviet effort in the military area to bring out advanced aircraft remains very high and competitive with our own. So I think in the aeronautics area we see a very vigorous thrust forward by the Soviet Union, in a program that I would say is fully competitive with that of the United States, with the possible exception of the civilian aircraft area, where our lead is very substantial.

When it comes to the military area, the Soviets are certainly challenging us on every front.

Mr. HECHLER. But isn't the investment by the Soviet Union in the future even greater by reason of the training of more younger aeronautical experts who will become leaders of the future?

Dr. PAINE. It is certainly true that the Soviet Union is building very greatly for the future in the area of aeronautics. I think that our own efforts at this particular time, particularly in civilian aviation, do give us some degree of confidence in the future, but it is certainly no time for us to slack off or to become overconfident in any way.

Mr. HECHLER One final question, before I yield to other members of the committee. How would you assess the importance of aeronautics today as contrasted with October of 1968, when you appeared before this subcommittee last? Is it the same importance, less important or more important, both in the task of NASA and in the challenge to the Nation?

Dr. PAINE. It certainly is no less a challenge. I think if anything we have seen in the last year the aeronautics area become an even more important part of our national effort, in several respects. One of these is with respect to the increasingly important part it is playing in our entire national transportation system. It continues to grow at a prodigious rate. This year the airports of New York City alone will handle 40 million people. The rate of growth seems to be definitely destined to continue into the future.

The other area, is the very important role that our aerospace industry plays in our whole national economy, and particularly with respect to our balance of payments overseas. The U.S. balance of payments and the exports that we have in the aerospace industry have now reached the point where some 240 percent (1969 estimate) of our total balance of payments is actually covered by the aerospace industry. It is one of the areas of our economy where due to the tremendous investment we have made in our technology and in our R. & D. in the past we can indeed compete very effectively in world markets. I think if it were not for the aerospace industry and the computer industry, we would certainly be in a very different position in world trade today.

Mr. HECHLER. Thank you, Dr. Paine. Mr. Pelly.

Mr. PELLY. Thank you, Mr. Chairman. I take it, Dr. Paine, that you don't agree with the economist who said the SST would adversely affect our balance of payments because it would encourage so many people to travel abroad, they would spend so much money that actually it would result detrimentally on our balance of payments.

Dr. PAINE. I thought that was a somewhat far-reached piece of reasoning.

Mr. PELLY. I think economists are generally clear-thinking people. I don't understand it. But that was a prize as far as I was concerned.

Dr. PAINE. Well, it is known as the dismal science, you know, Mr. Pelly.

Mr. PELLY. Well, I don't know what we would do if we didn't have economists to get us into arguments over the matter of spending policies and other matters that are vitally connected with policy.

Dr. Paine, you referred to the joint study of NASA and DOT for research and development. Is it possible that the conclusions of this study will be reflected in the upcoming budget of the President?

Dr. PAINE. The 1971 budget is now under consideration between NASA, the Bureau of the Budget, and the President. It will not be greatly affected by the study, although in the aeronautics portion of the budget we will be looking at the current status of the study for any clues we get. But the study is more likely to have any major impact on the 1972 budget.

Mr. PELLY. One witness before this committee said that a satisfactory level of research and development would be an increase of 40 percent or something like $70 million. I don't suppose you can project as to whether we will have a satisfactory level in the President's new budget?

Dr. PAINE. Well, I am sure the level will be satisfactory but exactly how much it will be is quite another subject, because the word satisfactory——

Mr. PELLY. Like "economist."

Dr. PAINE. Exactly. You have to take into account the entire fiscal program, and the pressure of other programs. We are trying to do our best in the aeronautical field, to which we have attached so much importance. At the same time it has to be done in the context of total demands.

Mr. PELLY. I would say it is one part of the budget which has very strong popular support. Some people don't see any advantage to landing men on the moon, but they certainly do as far as research and other matters affecting their safety when they travel by air as well as other upcoming problems which we hope will be overcome in the next few years.

That is all. Thank you, Mr. Chairman.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. First, I want to apologize for being late and not hearing your testimony. I am sure it would have stimulated more questions from me. I am interested—being from California, and particularly since my district includes Burbank, and the San Fernando Valley, which has a great deal of interest in aerospace activities.

I was wondering what is being done from your level to encourage students to get involved in areospace business. The need and the demand is going to grow, the demand for more trained young people coming out of school. I am sure it is something we are encouraging. I am just wondering what is being done, if anything.

Dr. PAINE. We do have a number of programs between NASA and universities working directly with the aeronautical engineering departments that I think give students unusual opportunities to use the facilities which NASA has in combination with their own studies. I think perhaps somewhat of a model of this has been the relationship that has developed between Stanford University and our Ames Research Center, which are situated only a few miles apart, in which we have an aerospace building on the Stanford campus and students there working in very productive circumstances who are also free to interact with the people at Ames and the facilities at Ames.

One particular project that comes to mind is a graduate student at Stanford, who happens to be a Peruvian, who has had some very advanced ideas with respect to rotors in the wing, to change the air distributions. These are things that can be checked out with NASA people in the wind tunnels at Ames in a very positive kind of a relationship I think.

But, Mr. Goldwater, there is another area which I am not very happy about that I must also mention and that is in my opinion we have not been able to attract enough of the young people just graduating from college into our NASA centers because of the severe cutbacks in our manpower that we have had over the last 4 years. It is a matter of

some concern to me that we don't have enough younger people coming to NASA itself. As we look through our centers, we see the staff being primarily composed of older people and one of the things we must do is find a way to get these young people, when they graduate from college and they are full of ideas, who don't know they can't do things for all the reasons that have previously been given, and who go ahead on the problem and try anyway.

Mr. GOLDWATER. Are you saying the demand is not really there, then?

Dr. PAINE. Well, there is a demand in the aerospace industry. I am concerned more with our ability to attract them into our Government laboratories to get more of a youthful outlook in our aeronautical research centers within NASA.

Mr. GOLDWATER. I believe there was some testimony here before this subcommittee to the effect that we were not graduating enough aeronautical engineers and scientists.

Dr. PAINE. We would like to see more graduates, too. I was simply saying there are two aspects to the problem. That is one of them. The other is that we are not bringing enough of those who graduate into NASA.

Mr. HECHLER. Will the gentleman yield on that point?

Mr. GOLDWATER. Yes, sir.

Mr. HECHLER. Is part of the fault in the universities? Someone observed to me the other day that the most recent textbook in aeronautics went all the way back to the 1950's. I wonder if there is enough leadership in the universities to generate the kind of interest that will cause younger people to go into the area of aeronautics.

Dr. PAINE. Mr. Chairman, you are getting somewhat out of my own direct personal experience area. It might be interesting for you to bring a few of the leading aeronautical engineering people in to comment on this from the universities.

Mr. HECHLER. Yes.

Dr. PAINE. But we do see some very vigorous leadership in the universities at this time and I am not aware we have a major problem.

Mr. HECHLER. You think it is a money problem then in NASA?

Dr. PAINE. Money and manpower ceilings, as we have been continuously reducing the number of people involved in the Nation's aerospace efforts within NASA. Obviously it is very difficult to bring new people in while you are moving large numbers of people out.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. Yes, I would like to ask one more question, Dr. Paine. I know that the United States has worked with the French and the British in the building of the Concorde, in exchanging information, and of course we buy some of their engines. What is the procedure? How do you proceed in the exchange of information between other nations, say other than the French and the British, the exchange of our technology in relationship to theirs and vice versa?

Dr. PAINE. There are in technological matters always two areas. One is the area of broad interest to all people, which is published in the open literature, and the second is that area that is proprietary, that has economic value to specific companies which they hold very closely, their own trade secrets if you like. NASA primarily operates in the former area, in the area of open, free exchange of information that

is required for all people. A good example is the effort to reduce the noise of jet engines, which we are anxious to do on a worldwide scale so that all the aircraft that fly in American skies, whether powered by Pratt and Whitney or General Electric or Rolls Royce, have the benefit of this kind of thing. Also when it comes to matters of air safety, when it comes to matters of the handling characteristics, and the way in which crews are trained to fly, we in NASA are able to adapt our simulators so pilots who will be flying the American SST or the British-French Concorde can become familiar with the cockpit features and we can work out some of the problems on the ground before the crews fly. These are the things we publish generally.

Mr. GOLDWATER. Is this strictly on a publication basis or do you actually have people in the field and do they have people over here?

Dr. PAINE. Yes, we exchange personnel. We have technical meetings. We attend meetings in other countries, we exchange equipment. We will, for example, have Canadian aircraft or French ideas with respect to helicopter rotors which we may have the facilities to test and we will test these for the French and then both countries get the advantage of these new ideas, which in the next generation after the prototype testing in laboratory the engineers will begin to look at for practical applications of a restricted type for each country.

Mr. GOLDWATER. To what extent say would this apply to the Soviet Union?

Dr. PAINE. With the Soviet Union the matter is somewhat different. The openness with which they publish their technical results is considerably more restricted than our own. We do see results from the Soviet Union. It was a matter of some interest to us that when Astronaut Borman visited Russia recently and one of the things he asked to see was the Soviet SST, he was given a very complete tour through the SST. He was allowed to sit in the cockpit and completely briefed on any question that he had. They were quite open about this.

Mr. GOLDWATER. Do we openly exchange information with the Soviets or is it just a gesture?

Dr. PAINE. It is more a case of the technical literature which is published in the United States which is open for them to buy, and the technical literature that is published in the Soviet Union, which is quite extensive, much of it is open for us to purchase. At international meetings in which various subjects are discussed there may be Soviet authors presenting papers as well as American authors.

Mr. GOLDWATER. Would you say it is sort of a family atmosphere in this area of astronautics?

Dr. PAINE. I would say in general it is a cooperative atmosphere.

Mr. GOLDWATER. Thank you, Dr. Paine. I have no other questions.

Mr. HECHLER. I have two other questions, Dr. Paine. I know your schedule is very tight and the committee would like to make sure that you get away from here fairly early. But I would like to put into the record a table of the Air Force expenditures on research, development, test and evaluation, and also on aircraft and related equipment. This table indicates that in fiscal year 1965 the Air Force total expenditure on R.D.T. & E. was \$3.176 billion. And it rose in fiscal 1968 to \$3.443 billion. Yet the expenditure of that amount on aircraft and related equipment declined during this period from \$803 million to \$539 million.

Now does this type of thing have any impact on what NASA could or should do in aeronautical research? It would seem to me that the squeezing down and decline of the emphasis of the Air Force on its expenditures on research and aeronautics, would place an increasing challenge on NASA.

Dr. PAINE. It does pose an increasing challenge on us, and it is particularly challenging because the R. & D. which NASA is carrying out today is the R. & D. on which the aircraft that will be flying in the 1980's will be based. So we have to look at the Air Force's short-range change in budget but we also have to ask ourselves where the Nation will be in the late 1970's and 1980's. It is also true that when the Air Force terminates production or is forced to change a program because of R. & D. unknowns that they encounter, such things as a problem with rigid rotors in helicopters or whatever, that this puts a particular and urgent requirement on NASA to get some of the fundamental answers that are required. This has been particularly true in complex areas like the interaction between the aerodynamics of airframes and engine inlet conditions in the advanced aircraft which the Air Force is now procuring. So that the changes in the Air Force program and the way in which their program progressed does have a major feed into the NASA program as we make decisions on the areas that are important for us, but we must always keep in mind the fact that it is a long-range thing and that we must be asking ourselves about the future questions as well as the current changes.

(The table of the Air Force expenditures on research, development, test and evaluation referred to is as follows:)

U.S. AIR FORCE R.D.T. & E. FOR AERONAUTICS

[In millions of dollars]

Fiscal year	Total R.D.T. & E. program	Aircraft and related equipment
1965	3,176	803
1966	3,339	845
1967	3,259	744
1968	3,426	762
1969	3,443	539
1970	3,157	645

Mr. HECHLER. The final question I would like to ask pertains to the Aeronautical and Space Engineering Board of the National Academy of Engineering which published in December 1968 the results of their study on various subjects in the aviation field. Would you care to comment since that study on what value these studies have had on NASA and what actions or steps if any have been taken since the December 1968 publication?

Dr. PAINE. We found this report to be a particularly fine piece of work, and those recommendations are being taken very much into consideration as we put together our plans for the future and as we construct our 1971 budget in the area of aeronautics.

I might also pay a compliment, Mr. Chairman, to the testimony before the subcommittee last week by the industry representatives, who also I think have examined the area of requirements in R. & D. and

have come up with some very thoughtful suggestions which we will take into account.

Mr. HECHLER. Thank you, Dr. Paine. I hope as a result of your testimony and the hearings of this committee that we may move forward to placing greater emphasis on aeronautics and the establishment of a national aviation policy that will provide the leadership in this area. We appreciate your appearing before this subcommittee.

Are there any further questions by members of the subcommittee? (No response.)

Mr. HECHLER. If not, thank you very much, Dr. Paine.

Dr. PAINE. Thank you, Mr. Chairman.

Mr. HECHLER. We are pleased to welcome back to the subcommittee Mr. Charles W. Harper, Deputy Associate Administrator for Aeronautics, the Office of Advanced Research and Technology, National Aeronautics and Space Administration.

Good morning, Bill.

Mr. HARPER. Good morning, Mr. Chairman.

Mr. HECHLER. Do you have a statement you would like to present to the subcommittee?

Mr. HARPER. Yes, sir; I do.

Mr. HECHLER. You may proceed.

STATEMENT OF CHARLES W. HARPER, DEPUTY ASSOCIATE ADMINISTRATOR (AERONAUTICS), OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

Mr. HARPER. Mr. Chairman and members of the subcommittee, as Dr. Paine said, we in NASA appreciate the opportunity to continue to participate in these hearings on aeronautics R. & D. The hearings of last year formed a very important input to NASA's planning. We expect the same to be true of the current hearings.

One objective of NASA's appearance today is to relate the statement and discussions of previous witnesses to NASA's activities and plans in aeronautics R. & D. This is particularly important since in most instances NASA is not a customer for the results of its aeronautical research and hence if that research does not relate to the user requirements NASA is not fulfilling its responsibilities.

Before commenting on the statements of previous witnesses, however, we would like to present NASA's view of the national aeronautics R. & D. question in order that our comments can be put in the proper context. This question can be stated simply as "to what extent should the Government support aeronautics R. & D. to assure aviation development along lines of maximum value to the Nation." The extremes of no Government participation or strong Government direction appear equally unsatisfactory. Through the assigned responsibilities of the Civil Aeronautics Board in controlling air routes, and the Federal Aviation Administration in operating the airways, the Government has already placed a value on air transportation at a national level. The question remains as to how far this direct involvement should be extended in the direction of research and development.

It is pertinent in this connection to recall that NASA was formed in order to sponsor the development of aviation for national benefit. A principal purpose was to develop and operate national research facili-

ties, representing a greater investment than the small industry could support, which would provide the flow of new technology required. Looking back, it is fair to conclude that this investment by the Government was a wise one, perhaps one of the wisest made. It laid the foundation for the military aviation that played a dominant role in World War II. The principles which led to the establishment of NACA were reexamined by a Presidential commission in 1947, and in a 1948 report entitled, "Survival in the Air Age," those principles were endorsed and their continuance recommended. The support that was continued by the Government through the 1950's allowed the development of the turbojet-powered supersonic military aircraft and laid the foundation for the tremendous expansion in civil air transport following introduction of the jet transports. The Government has a total investment in aeronautics R. & D. through the support of NACA and NASA of about $2.2 billion. Last year the U.S. civil aviation industry alone represented almost a $10 billion activity. This is a good return on investment.

In our testimony last year we discussed a number of opportunities for aeronautics R. & D. to provide the base for further major air transportation developments.

(*a*) We identified improvements in the subsonic jet transports leading to reduced noise, increased cruise flight efficiency, and reduced landing speeds, enabling use of smaller airfields. In the past year NASA has demonstrated the effectiveness of engine nacelle treatment to reduce radiated noise, has begun construction of a research engine to enable test of new principles of noise reduction, has undertaken modification of a small sweptwing aircraft to demonstrate improved cruise efficiency at higher speeds, and had many discussions with industry regarding technology for reduced approach speeds.

(*b*) We identified potential major advances in rotor craft through use of nonarticulated rotors, compound rotor craft, and tilt rotor aircraft which could provide acceptable solutions to the problem of quiet, efficient intraurban transportation. In the past year NASA has carried out extensive tilt rotor tests in cooperation with the Army and the French Government research group, has initiated with the Army a substantial program on nonarticulated rotors, and begun more detailed study of compound rotor craft.

(*c*) We discussed our conclusion that the STOL transport will come to fill a very important transportation role. In the past year the FAA reached the same conclusion and has urged NASA to accelerate its ongoing research on propeller- and jet-driven STOL aircraft, as well as defining additional research efforts for NASA to aid FAA in enabling early introduction of such aircraft in service. NASA is proceeding with modification of an OV-10 into STOL configuration to study propeller STOL operation and is on the verge of agreement with the Canadian Government for modification of a C-8 aircraft into STOL configuration to study jet STOL operation.

(*d*) We identified the supersonic transport as the successor to the subsonic jets for long-range transport. In the past year we have increased the depth of our studies on promising technology, of too high risk to incorporate in a first SST design, such as advanced avionics to provide aircraft and structural stability, on the stability of inlet-engine interactions to enable use of more efficient inlets, and on propulsion-airframe interaction to realize minimum drag in the critical

transonic acceleration portion of flight. We have initiated a joint flight research program with the Air Force to use the two YF-12 aircraft as national research facilities to verify wind tunnel findings and conduct research only possible in flight such as interaction of high-speed aircraft with high altitude turbulence.

In the past year also we have accelerated our efforts to obtain a proper assessment of technology values against the total air transportation picture, military and civil. We have agreed with DOD to participate in their systems planning at an early date to provide an important input to our program planning. We have provided required participation in the DOT/NASA study and use this to influence civil aviation program planning. It is increasingly clear that these activities are of prime importance. The impact of the turbojet engine was wholly underrated—while it was the lightweight engine that enabled the Wright brothers to fly, it was the turbojet that converted air transport from an adventure to a normal mode of travel. No forecast of 10 years ago showed the growth achieved, or predicted the noise and congestion problems, or predicted that the airport would begin to displace the harbor or railroad station as a center of city activity. No forecast showed that the long-range turbojet transport designs would be used for short trips of 100 or 200 miles with great success because of efficiency and ground travel congestion. It was not seen that air travel between Washington, New York, and Boston would reach more than 20,000 passengers a day when service was available. The re-emergence of military aviation as a powerful factor in the face of a nuclear stalemate was not anticipated. The growth of aviation to a point of being a major influence on the Nation's economy was overlooked. These now recognized factors, and many others, lie behind the increased attention being given aviation, and the actions being taken to circumvent its accumulated problems and exploit its potential for national benefit.

Examined against this overall picture, certain new factors stand out which will have a major influence on national aeronautics R. & D. activities in the future. Without question, the major factor is that a new aircraft concept must be seen as only one part of a total system, rather than as an isolated entity, in order to assess its value, and therefore the value of associated research. For example, a decade ago NASA could conduct vehicle research and FAA could undertake air traffic control development with almost complete independence; the jet transport was accepted into an existing system with very little disturbance. In part, this was because the jet transport represented just another evolutionary step in a process which had been proceeding for many years and in part because air transport still had a minor role in transportation so that its indirect effects were small. The situation today is quite different. A V/STOL transport system is not just a new aircraft but also includes new airports, new air traffic control, and so on, and their satisfactory interactions.

A second major factor is the change in relative importance to the country of air transportation. A decade ago air transport was a useful adjunct to other modes of travel and one element of the national defense system. From a national standpoint there was value in maintaining a healthy industry through some new technology development provided by the Government, but the requirement did not appear

critical. Today air transportation has become a critical part, both in a civil and military sense, of the daily operation of the Nation. Population growth and travel congestion on the ground point to air transportation as a major available option for the future. Thus the country's stake in continued healthy growth is much higher than a decade ago; formation of DOT is one recognition of this. Under these circumstances the role and extent of Government participation in aviation growth might well be very different from that which guided NACA activities.

A third factor is the very wide range of aviation systems possibilities facing both the civil and military users. Many systems are technically feasible, but certainly there are not sufficient resources to develop all nor would all prove to be of primary value if developed. A decade ago the options were fewer, and with relatively modest resources the Government, through NACA, could pursue technology related to most of those options. Today a process must be found to identify the promising concepts very early so that such resources as the Government chooses to assign can be allocated properly.

A fourth important factor, one discussed often in the past, should be pointed out again. In the period of evolutionary development of aircraft it was acceptable to make incremental advances in design. A new propeller or engine or wing could be fitted to an existing aircraft type and an improvement gained. Thus, in general, research needed only *to show that an element* of the vehicle could be improved and the idea could be adopted. Today, as has been emphasized repeatedly, the interactions of various elements of the vehicles are so great that a change in one invariably leads to changes in others. Adoption of a new technical principle thus entails a much higher risk until its favorable or unfavorable interaction with other elements is known. This problem has led to much discussion of the use of proof-of-concept or experimental hardware process whereby the simplest possible total system involving a new principle would be constructed to identify the effort required to allow practical adoption of the principle. This, too, is a problem much greater in magnitude than a decade ago. The Government, through NACA, carried out only a slight activity along these lines—the military carried the major share and civil aviation profited directly. More recently, the military have sharply reduced this activity while at the same time a need has grown for proof-of-concept activity in support of civil air transport requirements which would not have been met by military developments. Need for a quieter turbofan engine for civil transports is a good example. This growing gap between pure research and initiation of development seriously needs filling.

I would like now to turn to NASA's view of its role in aeronautical R. & D. as best as it can be established at this time, and in the light of the previous comments. There is little argument that NASA should carry for the Government a primary role in advanced research; this term implies study of those scientific disciplines which underlie advances in aeronautics. The work is most fundamental in nature and essentially free from consideration of the engineering problems associated with practical application of the research results. To the older disciplines of aerodynamics, materials and structures, and propulsion which NASA concentrated on, we have added fundamental studies

in flight dynamics, electronics and biotechnology as related to aviation. In the past 4 years we have made a determined effort to build up this area of unique responsibility of NASA. In that period the personnel directly involved have risen approximately from 600 to 1,200, and the resources approximately $6.6 million to $35 million. While this is encouraging progress, we are not satisfield yet with the level achieved. The proposed aircraft of today are far more sophisticated machines than those of even a decade ago. Correspondingly, to make progress, a much more thorough understanding is required of the basic physical principles involved. A particular problem—raised a few moments ago by Mr. Goldwater—in this regard has been the scarcity of new college graduates trained in aeronautics-related sciences and the severe limitation, as Dr. Paine pointed out, on NASA's ability to hire from those available. Aeronautical science R. & D. has a great need for an infusion of young scientists trained in the most modern scientific techniques.

The role and scope of NASA's activity vis-a-vis other agencies in applied research or technology is not clearly delineated. However, our concern over the national need to accelerate the pace of aviation development has led us to develop and propose research programs directed at the application of the advanced research findings. In developing these programs we have attempted to identify and focus attention on the most pressing military and civil problems. In arriving at this identification we have used the advice and recommendations of the DOD, DOT, and industry both through our research advisory committees and through informal discussion of specific problems in depth with all interested parties. Some of these activities were discussed earlier.

The examples of NASA work in applied technology discussed earlier are a logical extension of NACA/NASA's aeronautics R. & D. program which has historically concentrated on the aeronautical vehicle. However, as a consequence of the interaction of the vehicle with the remainder of the sytem that was mentioned earlier, new demands on NASA's R. & D. program are developing. Completion of the Alexander Committee report on air traffic control led to a request of NASA by DOT for research on the detection, control or dissipation of wing-trailing vortices, for example. The strength of these vortices from new, large aircraft is great enough to upset aircraft following too closely and thus puts a lower limit on aircraft spacing and airport acceptance rate. The FAA has asked NASA to undertake studies of airflow around elevated STOL ports to determine how these must be shaped to provide smooth airflow to allow safe city-center operations. The FAA has asked NASA to provide the support necessary for FAA personnel to study on NASA simulators the operation of the new large jets, the European supersonic transports and the U.S. supersonic transport. The FAA has asked NASA to cooperate in demonstration experiments which are designed to provide the information necessary to establish the role of satellites in aircraft communications and/or navigation and/or surveillance.

The Department of Defense also has begun to use NASA resources in a different way. Historically, NASA research has provided part of the technical base enabling DOD to undertake new systems development. During the development of those systems NASA has served in an advisory and support role to assist in realizing optimum use

of the new technology. More recently the DOD has brought NASA into its aeronautical system procurement planning at a much earlier stage. NASA has been asked by DOD to examine proposed new system requirements at a very early stage of definition. Where use of new or untried technology is needed to meet the requirements, DOD has asked NASA to develop new research programs or redirect existing ones to establish confidence in use of the new technology. Naturally, this draws NASA into research areas in greater depth than would be the consequence of its own research directed primarily at establishing new principles. NASA considers these responses to the DOD to be of the highest priority in its aeronautics R. & D. activities and responds to the maximum extent possible.

These comments are offered to illustrate an expanding scope of NASA aeronautics R. & D. activities and responsibilities whose limits are not yet clearly defined. Clear definition should be realized on the civil side with completion of the NASA/DOT study of R. & D. policy. The Aeronautics Panel of the Aeronautics and Astronautics Coordinating Board conducts continuing studies of the NASA and services R. & D. programs and recommends action to realize maximum benefit from joint use of the resources available.

The committee has expressed an interest in the impact that a space shuttle development would have on the NASA aeronautics R. & D. program. First, there is little doubt that meeting the technical challenge posed by the space shuttle will provide major new technical capabilities in many areas. Because the shuttle will be in part an atmospheric flight vehicle, it is reasonable to assume that some of these new technical capabilities will relate directly to aeronautical problems. If all the proposed shuttle operating requirements are to be met, a significant amount of aeronautics technology would be involved.

In the future considerable use will be made of personnel and facilities now directing their attention to various aeronautics problems. At the moment, however, the critical technology lies in determining shapes and structures for the shuttle which will meet launch and atmosphere entry requirements. Study of these problems has been carried in the past by personnel concerned with space vehicle technology. There is no reason to expect an early change in this. For most of the shuttle concepts proposed to date, a substantial amount of information on atmospheric flight characteristics exists already; this would be a primary responsibility of the aeronautics program. Thus, until a clear picture of the space shuttle design emerges from study of launch and entry problems, the impact of a space shuttle development on the aeronautics program would be anticipated to be small.

Mr. Chairman, in these comments I have attempted to describe the aeronautics R. & D. problem as seen by NASA and typical actions we are taking to assist in finding solutions. The final answer is not clear yet but I consider the problem is becoming well identified and that positive steps toward solution are being taken.

Mr. Chairman, that completes the statement I had prepared prior to hearing previous witnesses.

I have some further comments based on what I have heard from the witnesses, if you would like to hear them now.

Mr. Hechler. Yes.

Mr. HARPER. Or perhaps the committee would rather develop those through questioning.

Mr. HECHLER. No, I think perhaps you should develop those now, Mr. Harper.

Mr. HARPER. Colonel Anders emphasized the planned role of the Aeronautics and Space Council in leading the development of a national policy and program related to aviation progress in this country. NASA endorses this objective to the fullest possible extent. As other witnesses and I have emphasized, the various aspects of aviation development cannot be treated independently. The technical, operational, economic, and social implications must be treated simultaneously. This problem was not appreciated fully when, in the past, various responsibilities were assigned to the several branches of the Government. It is difficult for any one group, fully involved with its own problems, to provide the objectivity and overall view to integrate all related efforts. The NASA/DOT study is attempting to circumvent this difficulty by relieving assigned personnel of normal duties. Completion of this study will provide a process which can help the Government to determine, in a definitive manner, the consequences of any aeronautics R. & D. policy it chooses to implement. The choice of policy requires coordination of factors beyond the purview of NASA and DOT. The Aeronautics and Space Council is in a position to consider all of these factors and make policy recommendations. NASA anticipates continuing close association with the Council with this objective in view.

Mr. Beggs made two points during his appearance that bear importantly on NASA/DOT activities.

Mr. HECHLER. Before you continue with Mr. Beggs.

Mr. HARPER. Yes?

Mr. HECHLER. On your point about the National Aeronautics and Space Council, it would seem to me that this type of enunciation of national policy would have to come from the Presidential level.

Mr. HARPER. Yes, sir.

Mr. HECHLER. In a sense you are almost asking the Council to get involved in day-to-day policymaking activities. Did I misinterpret what you said?

Mr. HARPER. Somewhat, Mr. Hechler. Not day to day. I believe that the study should clarify the implications of any national policy. One could examine a policy in which the Government would take a very strong role in the direction and support of air transportation. The study will then show you the implications of this to all of the various agencies involved. Or you could reverse this process and propose an involvement of each of the agencies, the Civil Aeronautics Board, HUD, HEW, DOT, and so on, that have some part of this problem, and use the process developed by the study to determine what the policy should be.

I would look at the Council as the group that would take the lead in examining these two interactions and make a very positive recommendation to the President as to what policy or policies he should consider, but not a day-to-day formulation.

Mr. HECHLER. You may continue.

Mr. HARPER. To repeat, Mr. Beggs made two points during his appearance that bear importantly on NASA/DOT activities.

He noted that serious consideration is being given a joint DOT/NASA R. & D. activity patterned along the lines of the Army-NASA joint program described earlier by Dr. Paine. The advantages of such a step appear to be many. A number of NASA facilities are equally suitable for serving NASA or DOT needs; for example, the NASA simulator capability; the objectives toward which the two agencies would use the capability are different. It makes a good deal of sense for the two agencies to share the facility operational requirements in order that each research group can conduct research to meet its specific needs. An arrangement of this nature is now under specific examination. Mr. Beggs also pointed out the close interrelation between NASA research and DOT's defined transportation responsibilities. He identified the different problem of leaving a research program relatively free from constraints and yet making it responsive to DOT requirements; he described the efforts being made to bring together the planning activities of both agencies to obtain the best balance in the program. NASA has found this joint planning to be extremely useful and considers it should be continued not only to include program planning but also implementation.

The discussions with the representatives of Aerospace Industries Association, Mr. Perkins, and Mr. Kirschner raised three points of major concern to NASA. Both representatives addressed themselves to the question of increasing the more advanced research program of NASA to provide data base from which development can begin. As I stated in my testimony, NASA has made a very effective step in this direction. Nevertheless, the scope of advanced research has broadened sufficiently in recent years so that, as yet, NASA's effort is thin in many areas, as noted by Mr. Beggs. These speakers noted also the need for NASA to become more involved in operational-related research as contrasted to vehicle-related research. A good start has been made in this direction but many aspects of this technology are new to NASA and it involves relations with new agencies requiring new understandings of relative roles and capabilities.

Finally, both speakers touched on the "proof-of-concept" or experimental hardware dilemma and noted the absence of military activity to lead civilian development. This problem has been the subject of much debate over recent years and the answer is not yet clear. For the present, NASA has adopted the attitude that such efforts should be cooperative ones between the users (another agency or the services or industry), the manufacturers, and NASA. A few activities have developed along these lines although no generalized formula for sharing costs and effort have been established yet. It is our general conclusion that such division is necessary if satisfactory development is to continue, while at the same time maintaining competitive free enterprise, free from complete Government direction. An aspect receiving special attention is that of continuing to develop major new facilities too costly for industry alone to support and needed by both industry and Government.

Mr. Chairman, this concludes the additional comments that I had.

Mr. HECHLER. Mr. Pelly.

Mr. PELLY. Mr. Harper, it is always a pleasure to have you before this committee.

Mr. HARPER. Thank you.

Mr. PELLY. You are one of my favorite witnesses, I might say.

I think it has been said before, in different words before this subcommittee, that 10 years ago there was no forecast that showed the growth or projected noise and congestion problems, to recite your own words, or a prediction that the airports would begin to displace the harbor and railroad station. Was there any research going on 10 years ago in the way of population increases and projected problems, that you know of?

Mr. HARPER. There certainly was, Mr. Pelly. There are many reports of a decade ago.

Mr. PELLY. They missed the boat, did they?

Mr. HARPER. To my knowledge all of them underestimated the impact that air transportation would have. There is none that I know of that predicts or predicted satisfactorily the simple growth of daily air travel.

Mr. PELLY. Well, I assume that some agency of the Government is at fault. I can hardly blame it on NASA, because you were only organized about 10 years ago.

Mr. HARPER. That is correct. And NACA did not have this as a primary objective, although some of this was done in an effort to guide our own research. I think it is probably not quite fair to say some agency was at fault, since recognition of this finally came with the formation of the Department of Transportation.

Mr. PELLY. Well, I was going to say that we didn't have a Department of Transportation.

Mr. HARPER. Yes.

Mr. PELLY. It is their prime responsibility now, isn't it, to identify the problems of the future and then call on you for help in research in overcoming them?

Mr. HARPER. That is correct. They have the prime responsibility of defining the requirements that air transportation has to meet. These are then given to NASA, who picks up the responsibility of developing the technology that will meet these requirements, or enable the requirements to be met.

Mr. PELLY. Well, the purpose of the study that you are heading is to discover what the problems are going to be and the research that is going to be necessary—does that sum up exactly the joint study of DOT and NASA?

Mr. HARPER. Well, that is perhaps a slightly narrow definition of it, Mr. Pelly. One of the points that has been clear, as the work toward developing this study has continued, is the many other groups that should be involved in consideration of policy beyond just DOT and NASA. Certainly HUD, certainly HEW, certainly the Civil Aeronautics Board. They all have had a very important impact on the way air transportation developed. There has been no process developed in the past by which the influence of these various groups could be brought together and integrated to arrive at defining a path to follow. This is a very primary objective of this study, to show or to define all of the various groups that should be involved, to define their impact, in a way that one striving to reach a policy can be sure he has included all of the factors involved and not overlooked some, as was done a decade or more ago.

Mr. PELLY. To whom does the joint study report? To the President or to the——

Mr. HARPER. No, the joint study reports in the end to Dr. Paine and Secretary Volpe. They of course are not intimately involved in it at this point. The Assistant Secretary for Research and Technology in the Department of Transportation and myself head the day-to-day center of focus.

Mr. PELLY. Then it is probably not going to have too much influence on the direction of the 1971 budget of the President?

Mr. HARPER. Well not as a consequence of the study, but in preparation for the development of the study, in defining the process by which such policies will be reached, we found it immediately necessary to examine the plans of DOT and NASA in a much closer way than we had ever done before. We have reviewed each other's programs in extreme depth and submitted to the Bureau of the Budget, for example, a coordinated program between the two of us which reflects both DOT's long-range views of air transportation requirements at this time and NASA's research and technology program.

Mr. PELLY. You certainly don't have any difficulty identifying problems at the moment?

Mr. HARPER. No.

Mr. PELLY. Every college campus apparently has a group now that is vitally interested in quality environment?

Mr. HARPER. Yes.

Mr. PELLY. And I am sure that they are interested in the abatement of noise?

Mr. HARPER. Yes.

Mr. PELLY. The pollution—antipollution, and all of the things you are working on. I should think you would have an awful lot of public support for your work?

Mr. HARPER. It has been quite interesting, relating to the question raised by Mr. Goldwater earlier, that we have been asked to discuss with the colleges some of the unsolved aeronautical R. & D. problems that we see. Just last week I talked to the University of Maryland Engineering College. Two things have been quite interesting to me. One is to find the students quite surprised to see the number of very difficult technical problems that remain in aeronautics. They had the impression that this science had matured and there was very little to do. The other was the point you were raising, Mr. Pelly. Engineering students showed great interest in the social implications of what they are doing rather than strictly technical implications and these two seemed to come together in aeronautical engineering in a very interesting way for them.

Mr. PELLY. I have had some correspondence since the House passed the appropriations bill with the $95 million for the SST, and I think that some of these people who vote didn't have full information on it because they talked about smoke and noise and other things which you have been working on and certainly in second generation expect great improvements, do you not?

Mr. HARPER. Yes, that is correct, Mr. Pelly. It is quite clear, I think, that for a major step in technology such as the SST represents it would be foolish to risk carrying the technology farther than you had to to meet a minimum set of satisfactory requirements. Beyond that, just as

was the case for the subsonic jet transports, you can see many advances in the aircraft which will make it a much more effective aircraft, but not advances that you would incorporate in a first design.

Mr. PELLY. Well, I certainly have enjoyed your testimony here today and will say that I hope you are going to fight for adequate research funds for aeronautics. I think it is one of the vital programs today that is needed in this country. I am glad you are heading up this work.

Mr. HARPER. Thank you, Mr. Pelly. We appreciate your support.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. Mr. Harper, it seems that the industry in this whole effort of research and development seems to be working on certain conjectures and certain assumptions of what the actual need is or will be in the future. I think from your testimony I assume you agree with Mr. Kirschner that an overall system needs to be developed and an overall plan, giving projections for the needs of the future. I know there are an awful lot of studies being made in this area from different directions and by different agencies. How close are we to realizing an overall plan?

Mr. HARPER. I would doubt, Mr. Goldwater, that we will ever reach the point where we have a single overall plan that will extend very far into the future. I am sure this NASA-DOT study will represent just one first cycle. It will be reevaluated as the technology changes and as the national requirements change. That is why I feel it is very important to recognize this study as perhaps most useful in developing a process to do this in a most rigorous manner rather than arriving at a final, fixed-forever, decision.

The question of how fast we will begin to solve these problems is certainly an extremely difficult one. I think Mr. Kirschner discussed the difficulty of bringing full blown into being a V/STOL transportation system.

I myself doubt that it will ever be accomplished this way. It is too big an investment and too big a risk to take in one step. It seems to me far more likely that circumstances such as the Washington-New York air transportation problem will begin to bring into use smaller. slower aircraft but which can operate in a way that actually reduces the New York-Washington travel time. They will begin to operate on parts of airports adjacent to the main runways. Perhaps they will develop a special STOL port here and there. And the program will evolve from a start like that, rather than a very sudden step into a major new system. This is one of the reasons that NASA has been pressing the development of STOL aircraft for the previous years and pretty much I think the reason the FAA has come to agree that it is going to be an evolutionary process.

Mr. GOLDWATER. In other words, we really can't truly be that farsighted?

Mr. HARPER. I doubt that we can. And even if we could, I doubt that it would be best to try to introduce a new transportation system abruptly.

Mr. GOLDWATER. In other words—I can speak from a certain amount of knowledge of Los Angeles, where they have a tremendous number of commuter airlines using——

Mr. HARPER. Yes.

Mr. GOLDWATER. Fairchild F-27, is it?

Mr. HINES. Twin Otter.

Mr. GOLDWATER. Twin Otter. They use it very extensively. It makes possible a very successful commuter airline type system, all over a very large area. It seems to me the next step then would be, instead of using outlying airports, to actually use downtown helioports or building-top platforms. Maybe perhaps this is the way the industry will always proceed.

Mr. HARPER. I think it will tend to evolve that way, rather than take a revolutionary step. One of the questions that certainly faces everyone now in consideration of STOL operation in the city centers is the construction of a STOL port. It seems very difficult with land values as they are within a city to use area for that purpose alone. It becomes much more attractive to consider a complex, a building whose operations inside depend very much on air transportation, and then put the STOL port on top of the building.

We have a question of deciding just what sort of business would be contained within the building, so it would almost support itself, and a STOL port would not have to pay for the cost of absorbing that much land space in a city. These sorts of problems are part of what are being studied by the DOT-NASA group. It is necessary to begin to envision the interaction between business as it is carried on in a city and the air transportation system before you can decide how these things should develop.

Mr. HECHLER. Do you have a basic charter or set of instructions that the NASA-DOT group has enunciated as the purposes of their study or direction of it?

Mr. HARPER. Yes. I might even say, Mr. Hechler, we have several.

Mr. HECHLER. The committee would like for the record some more formal statement if you have such that indicates just what they are supposed to be doing and what direction they are going.

Mr. HARPER. All right. We will give you the latest stage of development of this.

Mr. HECHLER. Fine.

(The requested material follows:)

INTRODUCTION

On August 6, 1969, a memorandum was cosigned by the Chairman (Mr. Secor Browne) and the Vice Chairman (Mr. Charles Harper) of the Management Committee, directing the execution of this joint study. The direction authorized the Executive Director to begin structuring the study and soliciting the best qualified support whether in government or industry.

On September 8, 1969, the Under Secretary, DOT, provided the Chairman of the Subcommittee on Advanced Research and Technology with the basic charter for the study and a letter of transmittal introducing the charter (copy attached).

OBJECTIVES OF THE STUDY

Consonant with the recommendations of the Committee on Aeronautical and Space Sciences in Senate Report 957, the overall objectives of the study are:

(a) To analyze the relationship between benefits that accrue to the nation from civil aviation and the level of aeronautical research and development effort.

(b) To determine or develop criteria for determining the level of civil aeronautical research and development required to maintain U.S. leadership in civil aviation in the future.

(c) To identify what portion of civil aviation R&D should be sponsored by the government.

(d) To analyze the divergence and commonality of military and civil aeronautical requirements and assess the trends of benefits to civilian needs from military R&D.

(e) To identify civil aviation R&D anticipated to be undertaken in the private sector (to the end that civil aviation R&D efforts of both public and private sector can be viewed in an overall national context).

APPROACH

The whole conduct of the study will be iterative in nature, absorbing available information out of the existing activities, and being addressed by men of sufficient stature to exercise mature judgment. The first cycle will be largely intuitive, with the second much more rigorous and the third cycle addressed to critical gaps.

The approach to execution of the study recognizes that within the various agencies of the government and organizations representing industry resides a wealth of information, analysis reports, and proposed processes which can be used to structure the systems and evaluate the relative costs without necessarily initiating new programs. Therefore the assignment has been solicited of well qualified top level government administrators in four working areas whose day-to-day responsibilities closely parallel the characteristic problems that will be addressed by the working groups under their direction.

As their first activity, the staff of the study group and the designated working area study directors are structuring the specific tasks within each of the major areas. The basic framework within which that effort is developing is as follows:

(a) Projected civil air transportation needs and objectives will be identified in four categories: random systems (general aviation), short-haul systems, long-haul domestic and long-haul international. A set of hypothetical civil aviation systems will be defined which appear best suited to meet these needs and objectives. Ground transportation, air terminal access and egress as well as airways, airports, air vehicles and the air flight itself will be taken into consideration.

(b) Critical technologies (social as well as physical) will be identified for the elements of promising systems. The level of research and development effort necessary to provide the required technology and proof-of-concept will be estimated.

(c) The benefits which would accrue as the result of implementation of the promising systems will be identified. These benefits will be evaluated against the portion of the costs associated with the research and development activities.

(d) Various research and development activities which appear appropriate to be sponsored by the government will be identified, taking into consideration the level of effort required to meet transportation needs and requirements, the level of effort required to maintain leadership in civil aviation, and the related civil research and development contributions derived from the military programs.

In the final stages of the study, a higher proportion of the effort will be addressed to evaluation of benefits, identification of management options for organization and financing, and suggesting elements of policy recommendations for sets of conditions which have been developed.

PROGRESS SUMMARY

Since the September 8, 1969 letter to the Subcommittee, the following progress has been made in implementation of the study:

(a) The Management Committee for the joint study was established and the Executive Director (Mr. Lawrence P. Greene) proceeded to identify the resource requirements for the functional organizations, and proceed to fully structure the study in accordance with the DOT/NASA interagency agreement.

(b) A Study Advisory Committee was developed through the resources of the National Academy of Engineering. The Committee membership is now established with 21 members representing top level management leaders in the total transportation community. The next meeting of this Committee is scheduled for December 18, 1969 when their advice and counsel will be solicited after reviewing the study organization, program structuring, and progress to that date.

(c) Working Groups Directors have been identified for the three primary areas of aeronautical vehicles, airport systems, and airway systems.

(d) On November 2, 1969, the Department of Defense (Dr. John S. Foster, Jr.) acknowledged the DOT/NASA invitation to participate in the study and agreed to supply the desired personnel and material support. Negotiations are now underway to select three military aviation experts for full-time duty with the study organization.

(e) To provide representations from the Civil Aeronautics Board, an invitation to participate was forwarded to the Chairman on November 12, 1969. Ne-

gotiations are now underway to provide a full-time CAB member to the study group.

(*f*) Two contractor support efforts are now underway. Booz-Allen, Inc. is under contract to complete the "Historical Benefits Study" covering the aeronautical research and development history since 1945; developing assessment tools for evaluating the benefits accrued from those investments, and validating those assessment tools for use against future aeronautical R&D program projections. A second contract was awarded to Operations Research, Inc. to perform the function of integrating activities within the study. This will include the development of master schedules, task networks, management networks, reporting formats and display devices.

The Mission and Systems Analysis Group is the full-time staff assigned to Mr. Lawrence P. Greene, who also functions as the Study Program Manager. This staff is composed of both DOT/NASA full-time government employees (ten). Since late September, this group has been involved in structuring the study to include developing (1) the specific tasks for the Working Groups, (2) a technology assessment of available capability and projections of future technology goals and objectives, (3) the compilation of past, current and future activities and studies relevant to this study, (4) the initial iteration of the study to validate the selected methodology and (5) implement the plans for program management and control to achieve the objectives of the study.

OFFICE OF THE SECRETARY OF TRANSPORTATION,
Washington, D.C., August 6, 1969.

Mr. LAWRENCE P. GREENE,
Executive Director, Civil Aviation R.&D. Policy Study, Department of Transportation, Washington, D.C.

DEAR MR. GREENE: In an exchange of letters on April 25, 1969, Mr. James M. Beggs, Under Secretary, and Dr. Thomas O. Paine, Administrator, NASA, agreed on a general approach to a joint, in-depth study of the nature, cost and benefits which accrue from Civil Aviation Research and Development. The attachment, transmitted herewith, is an expansion of the original agreement which has been developed through a coordinated effort of our offices. It represents the implementation plans for the over-all management of the study.

You are hereby instructed to proceed with the execution of this study. You are to consider this letter the authority to solicit the necessary support from other elements of the DOT, NASA, and other government agencies on behalf of the Management Committee. In addition, you should keep in mind the importance of getting the best qualified contributions to this effort whether in government or industry. You are also instructed to initiate coordination with Dr. H. Guyford Stever, President, Carnegie-Mellon University, who has agreed to serve as Chairman of the Study Advisory Committee.

Finally, although the complete study is expected to take approximately 18 months to complete, the importance of providing immediate assistance to the two agencies in developing their programs of Aeronautical Research and Development cannot be overemphasized. Accordingly, you are asked to be prepared to contribute to the classification and identification of aviation oriented research and development programs of the proposed FY 1971 budget when it is submitted to the Bureau of the Budget later this year.

The critical milestones for the total study shall be: September 30, 1969 for the full structuring of the program and the first review with the Study Advisory Committee, April 30, 1970 for initial contributions to the FY 1972 budget development, and September 30, 1970 for significant contributions to the submittal and substantiation of the FY 1972 budget. It is intended that the major elements of this study and its recommendations shall be available for review with the Secretary of Transportation and the Administrator, National Aeronautics and Space Administration, before the end of calendar year 1970.

Sincerely,

CHARLES W. HARPER,
Deputy Associate Administrator (Aeronautics), OART, NASA,
Vice Chairman, Civil Aviation, R. & D. Policy Study.

SECOR D. BROWNE,
Assistant Secretary for Research and Technology,
Chairman, Civil Aviation, R. & D. Policy Study.

Attachment.

Civil Aviation Research and Development Policy

INTRODUCTION

The Senate Committee on Aeronautical and Space Sciences,[1] and later the House Subcommittee on Advanced Research and Technology,[2] highlighted the need for a single national policy for aeronautical research and development, including especially a more comprehensive and coherent policy in the area of civil aviation as an important element of the overall transportation system. The Senate Committee recommended,[3] and the House Subcommittee concurred, that the Department of Transportation and the National Aeronautics and Space Administration should undertake an indepth study of the relationship between the benefits that accrue to the Nation from civil aviation and the level of aeronautical research and development effort. This study should try to determine (or develop criteria for determining) the level of civil aeronautical research and development required to maintain U.S. leadership in civil aviation in the future. It should "also include a detailed analysis of the divergency of military and civilian aeronautical requirements in order to assess better the diminishing benefits to civilian needs from military R&D".

Subsequent to the findings and recommendation of the Senate Aeronautical and Space Sciences Committee, the National Aeronautics and Space Council held a meeting on May 22, 1968, at which it was proposed by Mr. Webb that the Department of Transportation take the lead in developing a plan for carrying out the joint DOT/NASA study effort. The importance of participation by the Department of Defense was also recognized.

The Bureau of the Budget has also displayed a keen interest in the creation of a unified civil aviation research and development policy, especially as it includes consideration of the level of effort and makeup of the coordinated civil aviation research and development program that is required by the Nation. In this connection, too, it is important to identify not only what portion of the responsibilities for performing this research and development should be assigned to the Government, but also what the division of this portion should be between the various agencies of the Government.

In light of these considerations, the Department of Transportation and the National Aeronautics and Space Administration have outlined a study plan for the development of a comprehensive and coherent national policy for civil aviation research and development. Implementation of this plan will lead to the identification of civil aviation research and development programs recommended for sponsorship by the Federal Government. Related research and development anticipated to be undertaken in the private sector will be similarly identified to the end that the civil aviation research and development efforts of both the public and private sector can be viewed in an overall national context.

This paper outlines the study plan, recommends a method of implementation, and estimates the time requirements for its completion.

PROPOSED STUDY PLAN

The proposed study plan is schematically portrayed in Figure 1. For ease of discussion, the plan has been divided into four "steps", the first of which is aimed at defining the projected civil aviation transportation requirements in relation to other transportation requirements.

The second step will identify the several types of civil aviation systems which appear individually and collectively best suited to satisfy the total requirements. The third step will analyze these systems to identify where and what R&D are limiting factors in achieving operational capability of these new air transportation systems. Two important inputs to these analyses will be provided by the study of the historical benefits of R&D to the advancement of civil aviation and the study of the spin-off from military R&D to civilian applications.

[1] Hearings on Aeronautical Research and Development Policy held before the Committee on Aeronautical and Space Sciences, United States Senate, Ninetieth Congress, First Session, January 25–26 and February 27, 1967.

[2] Hearings on Aeronautical Research and Development held before the Subcommittee on Advanced Research and Technology, Committee on Science and Astronautics, U.S. House of Representatives, Ninetieth Congress, Second Session, September 24, 25, 26, 30; October 1, 2, and 3, 1968.

[3] Senate Report No. 957. "Aeronautical Research and Development Policy," January 31, 1968.

The fourth step in the study plan will be to analyze the resulting R&D requirements in terms of the rate at which they are satisfied depending upon the level of effort of R&D. In addition, this last step in the study will identify the appropriate distribution of R&D efforts among the more desirable aviation systems and between Government industry, and universities. Finally, there will be the determination of the distribution of the Government's portion of the effort between DOT, NASA, and DOD.

It is noted on Figure 1 that a number of feedback loops are provided between the several phases of the study and that mission and systems integration and analysis is provided for as required in proceeding from one phase to another. It is anticipated also that additional supporting studies and analyses may be required for the successful performance of this overall operation. While these studies are not defined at this time, the probability is acknowledged by the block, "Supporting Studies and Analyses", shown on Figure 1.

CIVIL AVIATION R&D POLICY STUDY

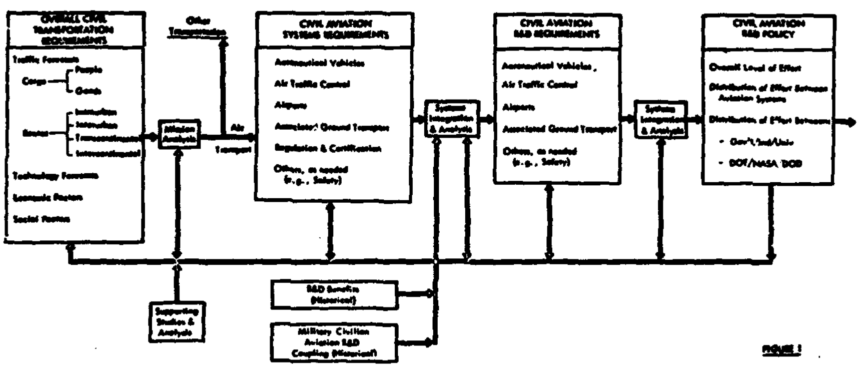

FIGURE 1

Finally, it should be noted that this study is actually a very important part of a larger transportation systems study. As such, the results from this study, as well as the treatment of an integrated transportation system will be repeatedly evaluated as they become available to insure compatibility. Initially, however, the civil aviation R&D study will make use of existing traffic forecasts. It will, of course, be necessary to examine critically these forecasts to assure that they give all possible consideration to the impact of new technology and to assure that they are based on the estimated role of air transportation in the context of an over-all transportation system rather than as an independent part.

IMPLEMENTING THE PLAN

Implementation of the process briefly described in the foregoing paragraphs will be accomplished through a combination of in-house efforts, contract efforts, and committee activities. Responsibility for the over-all management and coordination of the effort will be assigned to a Management Committee. Specific studies will be carried out by appropriate Working Groups reporting to the Management Committee; staff support to the Management Committee will be provided by a Mission and Systems Analysis Group; and the Management Committee will be provided with expert and broad advice and counsel in the conduct of the study by a Study Advisory Committee (see Figure 2).

The Management Committee

The Assistant Secretary for Research and Technology, DOT, will be Chairman of the Management Committee and the Deputy Associate Administrator for Advanced Research and Technology, Aeronautics, NASA, the Vice Chairman. Through these two positions the total program will be under the joint aegis of the Administrator of NASA and the Secretary of Transportation. The third member of the Management Committee will be the Executive Director (Program Manager) of the study. He will be assigned full time responsibility for the execution

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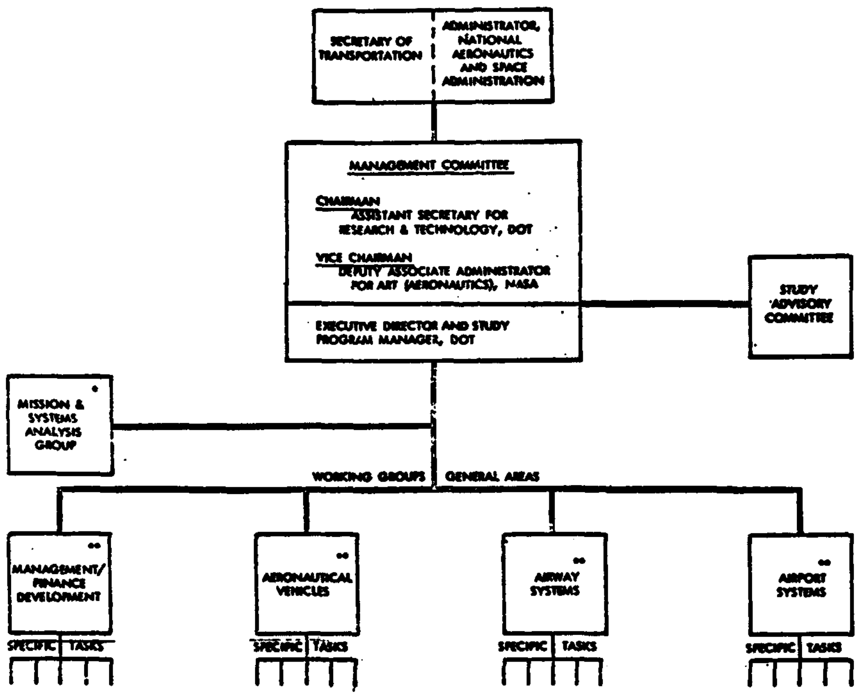
and control of this study and will be responsible, on behalf of the Chairman and Vice Chairman, for the over-all planning, coordination and integration of the various efforts required to effect the implementation. The remaining complement of the Management Committee shall consist of selected Working Group Study Directors (to be determined) and the Chairman of the Study Advisory Committee (Ex Officio).

The Executive Director will serve as personal agent for the Chairman and Vice Chairman in matters pertaining to the execution of this study and will assist them in the reporting to, and coordination with, the Administrator (NASA) and Secretary (DOT), the Study Advisory Committee, the National Aeronautics and Space Council, the Senate Staff and such other persons or organizations which shall be designated. He will exercise prerogative on behalf of the Chairman and Vice Chairman in the following ways:

CIVIL AVIATION R&D POLICY STUDY



FULL TIME STUDY COORDINATION AND INTEGRATION STAFF

** THESE WORKING GROUP DIRECTORS SHALL SERVE ON THE MANAGEMENT COMMITTEE.

1. Establish scope of working group studies to be accomplished.

2. Establish schedules and budgets for in-house and contract work in support of studies, monitor performance, direct, redirect, and control the various efforts necessary to complete this study.

3. Define and recommend implementing procedures for in-house vs. contract activity and control the assignment of contracted effort.

4. Select and assign (in coordination with the Chairman and Vice Chairman) Working Group Study Directors.

5. Review and coordinate the efforts of the designated study (working group) directors.

6. Continually reassess the progress of the program, maintaining particular cognizance over the integration and evaluation of the results in comparison to identified requirements.

7. Assure that broad, unbiased, contributions are provided to the study efforts to assure proper identification and understanding of the relative roles which

DOT, NASA, DOD, other Government agencies and industry should play in this vital work and will coordinate such activities with the other Government agencies involved.

8. Review, develop, and recommend to the Chairman/Vice Chairman procedures, programs, and subjects for evaluation by the Study Advisory Committee.

The Executive Director (Program Manager) will have administrative responsibility for a small staff (the Mission and System Analysis Group, see below) to assist him in the day-to-day study management, to define the interface relationships between elements of the study, as well as between other related technologies, programs, and transportation requirements, and to carry out systems analyses and integration of the various elements of the over-all study.

Study Advisory Committee

The Study Advisory Committee will be established to provide the Chairman and Vice Chairman of the study with expert and broad advice and counsel in the conduct of the study. To insure the achievement of this end, the Committee will be formed utilizing the National Academy of Engineering and will be constituted with top level leaders in the air transportation field, from other Government agencies, industry, and universities. The Committee will meet periodically to review the status and progress of the over-all study activity and its many separate elements, and will advise the Management Committee of its views on these matters as well as content of the study. The Chairman of the Advisory Committee will serve on the Management Committee in an *ex-officio* capacity and thus will be kept in very close touch with the over-all study and its many elements. In selecting representatives from the private sector to serve on the Advisory Committee, the views of a number of private organizations will be solicited in seeking individuals of competence and recognized stature. These organizations include the Air Transport Association, representing the airline industry; the Aircraft Owners and Pilots Association, representing the "general aviation" users; the Aircraft Industries Association, representing the vehicle manufacturers; the Electronics Industries Association, representing the electronics manufacturers; the Airport Operators Council, representing the airport interests; the National Academy of Sciences, representing the scientific community.

Working Groups

Working Groups will be formed to carry out specific elements of the over-all study as may be required. Typical Working Groups are identified in Figure 2; the Groups shown there are representative of those which will be formed, and not necessarily all-inclusive. Certain of the study elements shown on the figure have already commenced, either to meet other related responsibilities of the Department of Transportation and the National Aeronautics and Space Administration, or to anticipate the requirements of this plan and attempt to shorten lead times necessary for its accomplishment.

Working Group Directors will be from DOT or NASA, as appropriate, chosen by the Executive Director in coordination with the Chairman and Vice Chairman. All working group directors will assist in the overall study definition, implementation, and integration through the auspices of the Executive Director's Staff. Thus, they shall be well informed about the definition of tasks and boundary conditions, the values of the outputs, and the importance of the results.

It is planned that the working groups will have representation from not only DOT and NASA, but also from the Department of Defense and other appropriate government bodies. In addition, expert help from the private sector will be sought, as appropriate, with individuals serving on a paid-consultant basis and contracts awarded to groups as needed for specific tasks.

Mission and Systems Analysis Group

While each of the study elements will have a specified set of outputs, none of them can be conducted without some consideration of the other system elements. For instance, the air traffic control study cannot be conducted without consideration of vheicles, airports, and noise. As a result, two things become obvious. First, careful and guided coordination between study efforts will be required; and second, each of the studies in each phase of the total program, will have some input to the other areas of study (cross talk). As an example, in the activity pertinent to the R&D Requirements block, critical information pertaining to vehicles will come, not only from the systems integration and analysis, but will also be provided by studies on noise, air traffic control, safety, etc.

To assure this integration at all phases of the study, the Mission and Systems Analysis Group will be formed. It will consist of a small number of full-time DOT and NASA personnel of appropriate technical expertise, augmented by part-time support, as required, from these and other agencies as well as, the private sector. It will be supported by contracted effort and designated in-house assignments to functional elements of the parent organizations, as required. The Mission and Systems Analysis Group will be directed by the Executive Director of the over-all study and the group will thus serve the Management Committee as its immediate staff.

Study Schedule

The length of time for carrying out the study should be about fifteen months. Allowing three months for the study to become fully activated, this results in a time period of eighteen months to accomplish the total task described in this paper. Preliminary results should be available for the FY 1972 budget exercise. Execution of the work shall be in an iterative manner (Figure 1). Successive steps of determination of requirements, comparison of technological capability, identification of system concepts, analysis, comparison of results to original requirements, redefinition as necessary until the final determination of character, level of effort, and distribution of effort between various departments of government, academia, and industry is recommended.

SEPTEMBER 8, 1969.

Honorable KEN HECHLER,
Chairman, Subcommittee on Advanced Research and Technology, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. HECHLER: In view of your deep interest in applying advanced technology to the total field of transportation, I felt it would be worthwhile to call your attention to the joint Department of Transportation (DOT)/National Aeronautics and Space Administration (NASA) Civil Aviation R&D Policy Study which we have recently initiated. I know that your Subcommittee on Advanced Research and Technology was instrumental in suggesting action on this subject. Furthermore, I know that you have been an active advocate of such effort.

The need for development of a well-defined relationship between government and industry, and between various government agencies involved in aviation development is clear. This, of course, concerns primarily the DOT and the NASA but also involves the Departments of Defense (DOD) and Commerce, as well as other executive departments, and the private sector of our manufacturing and operating industry. I am extremely enthusiastic about the prospects for developing a national plan for the enhancement of all civil aviation as a result of this study effort.

We have constructed an approach that we believe will consciously examine sufficient alternatives to give credence to the recommendations for Federal Policy. Because of this, it will require adequate time to complete and provide significant results upon which to base such recommendations. The scope of this study covers the entire aviation complex of air vehicles, airways and airports. Because of its breadth and the importance of conscious examination of the benefits and costs, we have set out an 18-month schedule for this study. We are not content to wait that long for any results, however, and expect that the study will produce preliminary results for review with your staff at periodic intervals. We are encouraging Mr. L. P. Greene, the Executive Director of the study, to maintain direct contact with the staffs of the interested committees of both the Senate and the House.

The Department recognizes the responsibility to pursue identification and encourage development of a truly balanced total transportation network, fully integrated betwen modes, making it possible and attractive for the user to exercise viable options. Transportation represents the arteries of our society, making it possible for our life blood (goods and services) to be distributed to the benefit of our total well-being. It is one of the means to greater opportunity and cultural development. I feel that the effort embodied in the joint civil aviation R&D study represents one major step toward realizing these objectives.

In each case, I take action to notify the principals of committees involved in the transportation program, I am forwarding the management directive through which this team is operating. You will note from the cover letter, our instructions are clear to have continuing evaluation of the content

and progress of the study. I invite any comments which you might be moved to offer.

Sincerely,

JAMES M. BEGGS.

Mr. HARPER. I would point out this is a very difficult job. It has been tried by many people. Each time it has failed because some one group has tended to make assumptions that slanted in their direction. The effort here is to very carefully assure ourselves that we are not making untenable assumptions.

Mr. HECHLER. Now you were here when Mr. Perkins testified, and I think he stated quite graphically the frustrations involved in the field to freeze a particular type of V/STOL development.

Mr. HARPER. Yes, sir.

Mr. HECHLER. This is just one small piece of a very, very large problem. Now you are a man who is not easily frustrated. Can you give us some example of areas that concern you in the aeronautics field, in the absence of a definite policy?

Mr. HARPER. Well, when you say "concern," do you mean areas that we have chosen in the absence of a policy to pursue in any event?

Mr. HECHLER. Well, what I was really seeking for was areas where you failed to make progress or there has been lack of activity or support by reason of the absence of a definite type of decision or leadership as was pointed out in V/STOL by Mr. Perkins.

Mr. HARPER. Well, in the broadest possible sense I would think the question of the extent to which general aviation and general aviation now including not only the private pilot but the charter or taxi operation—the extent to which that will become a significant part of our transportation system and therefore the extent to which the Government should support it. To date the actual investment in R. & D. through the Government has been very, very low in this area compared to the emphasis in other areas, and yet it is one of the most rapidly growing facets of air transportation in the country. You have on the one hand the extremist who says that is only useful to the very wealthy man or to the major companies and Government should not have to provide support. On the other extreme is the observation that it will become very key as a short-haul transportation link feeding major trunklines. There is no decision but a great deal of argument here as to what role if any the Government should play in supporting the whole field of general aviation.

To get more specific, there are certainly the questions that Mr. Perkins and Mr. Kirschner raised about the difficulty of choosing between the many competing types of STOL and V/STOL aircraft. The STOL aircraft are closer to operational status if you consider them as a propeller-driven type. The airlines say they never want to return to propeller-driven aircraft. One is a fact and the other is an objective conclusion, and we are searching for some way to define right now for the airlines whether propeller-driven aircraft would really prevent passenger use the way they say. For that reason they have pressed us to accelerate the development of jet STOL very rapidly, so they can maintain the long overhaul periods and the ease of operating jet aircraft.

The choice between the various V/STOL aircraft modes is dependent very much on whether you expect to see a city acceptance of this or whether it is going to operate on more outlying districts. And this

is the kind of a question that needs yet to be answered by longer discussions with such groups as the New York Port Authority, in order for us to define where we should most emphasize the technology.

Mr. HECHLER. I recall about 30 years ago a hearing of the Senate Appropriations Committee being chaired by Senator McKellar of Tennessee, and the witness was the Director of the Bureau of the Budget, Harold Smith, and Senator McKellar asked him "How many positions do you have in the Bureau of the Budget that are devoted to research?" And very quickly the Director of the Bureau of the Budget answered "None." Senator McKellar smiled triumphantly as though he had killed some particular snake, and he said "Good. Good. Thank you."

Now I wonder how much the activity of NASA is really devoted not so much to examining particular power systems or machines or types of aircraft, but is really devoted to planning and forecasting requirements, in other words, thinking? I might say that my attitude is somewhat different from Senator McKellar on this. So I would hope you don't say triumphantly that you have nobody who devotes his time to thinking.

On page 12 of your statement, where you answer this question, I notice that you mentioned that DOD brings NASA into its aeronautical system procurement and planning at an early stage, and NASA asks DOD to examine proposed new system requirements. Well, this is military?

Mr. HARPER. Yes.

Mr. HECHLER. I assume DOT would do this on the civilian side. But does this merely mean that NASA with respect to both military and civilian responds to outside agency requests, or how much of your activity really is devoted to forecasting and planning requirements in this very critical area of aeronautics?

Mr. HARPER. A considerable amount of our activity relates to this in various degrees. The Mission Analysis Division of OART, which is at the Ames Research Center, spends all of its time on this forecasting of requirements, and there are about 15 people attached to the aeronautics side of this. They are doing to a degree, a small degree, the sort of study that DOT should be carrying out. And this was instigated several years ago when we realized we began to need some direction for our technology efforts, rather than just the interests of a scientist. When our Center people propose a new technology program, we now ask them to go beyond the physical sciences in justifying the program. It has to be more than something you can do. It needs to be something of value when you have done it. This is a rather new field for scientific people to indulge in and yet I think it is very good and educational for them. We ask them to look at its impact, to the extent they can, on an air transportation link. They have to consider its impact on a community in which it will operate, for example, we ask our scientists to project for us what this will do to the noise problem. So I think there are very few of our people, except some of the most basic research groups, that are not now giving consideration to the implications of the research they are doing, in either a civil or a military sense, much more so than we did in the past.

Mr. HECHLER. Mr. Fulton, we are pleased to have you with us. Do you have any questions you would like to pose?

Mr. FULTON. I am glad to be here.

My question is on the effect of the so-called Mansfield amendment that requires the Department of Defense only to do research of a military programmatic or military-connected nature. Have you been in touch with the Department of Defense on picking up this kind of basic or not indirectly military-conducted research? What is the situation? What are you planning ahead on that? Are you going to sit and let this research all go by the board or are you going to try to move in and fill a gap which certainly will exist in basic and even general applied research in this country?

Mr. HARPER. Our most specific effort, Mr. Fulton, in connection with that has been a very intensive and continuing review with the three services of their R. & D. programs, through which we are trying to identify those that are sufficiently far removed from direct military application but have that sort of implication in the long run, that could be absorbed into NASA's program or NASA could join with the services to conduct some of this work.

Mr. FULTON. Could I just say to the chairman if a statement were presented I think it would be good for the record, rather than have the detail given here. Secondly I want it more in relation to the earthquake that the Mansfield amendment has caused on the shift of research in the Department of Defense.

Where is it going? It isn't just as though you have been dealing casually. I want to see the result of this tidal wave and this earthquake. As you know, the President's science adviser thinks it is a tragedy that such a strict amendment has been put in.

Mr. HARPER. Yes, we can supply that for the record.

Mr. FULTON. Thank you, Mr. Chairman.

(The information is as follows:)

In formulating NASA's basic research programs in aeronautics and space, we have given close attention to the basic research activities of DOD to assure that where we have common interests our efforts are complementary and not duplicative. We have contacted appropriate DOD officials specifically with regard to Section 203, and if, in the review of DOD's basic research activities, it is determined that Section 203 would proscribe DOD programs directly relevant to NASA's programs, we will make every effort within the resources available to assume support of such activities.

Mr. HECHLER. Thank you, Mr. Fulton.

We will also pursue that question with the Department of Defense witnesses that appear before this committee later this week.

Mr. FULTON. There is one other point on the future. May I ask one, Mr. Chairman?

Mr. HECHLER. Mr. Fulton.

Mr. FULTON. The Air Force, of course, has moved out of the space business as such, which is what they should have done long since. In moving out there has been a transfer of astronauts to NASA. I had been thinking that, on projection, there are already too many astronauts in NASA, considering the budget cut to the level on which NASA is now operating on manned space flight.

(The additional material submitted is as follows:)

The basic organizational structure of the Astronaut Office is by flights with permanent assignment of astronauts to these flights. Flights A, B, and C are mainline Apollo crews. The fourth flight contains all AAP personnel. All personnel are in training for future flights.

The training period for an astronaut extends over several years, particularly with the increased complexity of future missions because of the increased experiments and applications demands. Depending on how future programs evolve in the AAP and post-AAP mission period, these assignments can be reevaluated.

The following alphabetical roster indicates duty assignments:

Active NASA Astronauts	Flight assignment	Crew assignment
Col. Edwin E. Aldrin, Jr	Flight A	Prime on XI.
Dr. Joseph P. Allen	AAP	
Neil A. Armstrong	Chief, Flight A	Do.
Capt. Alan L. Bean	Flight A	Prime on XII.
Maj. Karol J. Bobko	Completing studies, University of California.	
Vance D. Brand	Flight A	Support XIII.
Lt. Col. Gerald P. Carr	do	Support XII.
Comdr. Eugene A. Cernan	Flight B	Backup on XIV.
Dr. Philip K. Chapman	AAP	
Col. Michael Collins	Flight A	Prime on XI.
Capt. Charles Conrad	Flight B	Prime on XII.
Col. L. Gordon Cooper, Jr	Assistant for Space Shuttle Program	
Lt. Comdr. Robert L. Crippen	AAP	
Walter Cunningham	Chief, AAP Flight	
Maj. Charles M. Duke	Flight B	Backup on XIII.
Lt. Col. Donn F. Eisele	Section Chief, AAP	
Dr. Anthony W. England	AAP	
Lt. Col. Joe H. Engle	Flight B	Backup on XIV.
Lt. Comdr. Ronald E. Evans	do	Do.
Maj. Charles G. Fullerton	AAP	Support on XIV.
Dr. Owen K. Garriott	Section Chief, AAP	
Dr. Edward G. Gibson	AAP	Support XII.
Capt. Richard F. Gordon	Flight A	Prime on XII.
Fred W. Haise	Flight C	Prime on XIII.
Maj. Henry W. Hartsfield	Completing studies, University of Tennessee.	
Dr. Karl G. Henize	AAP	
Dr. Donald L. Holmquest	AAP	
Lt. Col. James B. Irwin	Flight B	Backup on XII.
Comdr. Joseph P. Kerwin	AAP	
Dr. William B. Lenoir	AAP	
Dr. Don L. Lind	AAP	
Maj. Jack R. Lousma	Flight C	Support on XIII.
Capt. James A. Lovell	Chief, Flight C	Prime on XIII.
Lt. Comdr. Thomas K. Mattingly II	Flight C	Do.
Lt. Comdr. Bruce McCandless II	AAP	Support on XIV.
Comdr. Edgar D. Mitchell	Flight B	Prime on XIV.
Dr. F. Story Musgrave	AAP	
Maj. Robert F. Overmyer	AAP	
Dr. Robert A. Parker	AAP	
Maj. Donald H. Peterson	Completing studies, University of Tennessee.	
Lt. Col. William R. Pogue	Flight C	Support on XIV.
Maj. Stuart A. Roosa	Flight B	Prime on XIV.
Dr. Harrison H. Schmitt	Flight C	
Russell L. Schweickart	AAP	
Col. David R. Scott	Flight B	Backup on XII.
Capt. Alan B. Shepard, Jr	Astronaut Office	Commander, Apollo 14.
Col. Thomas P. Stafford	Chief, Astronaut Office	
John L. Swigert	Flight C	Backup on XIII.
Dr. William E. Thornton	Will complete pilot training in April 1970.	
Lt. Comdr. Richard H. Truly	AAP	
Comdr. Paul J. Weitz	Flight A	
Maj. Alfred M. Worden	do	Backup on XII.
Comdr. John W. Young	Chief, Flight B	Backup on XIII.

Have you made any projection on the use of astronauts? No. 1, it is unfair to the taxpayer to keep them on if there is no earthly use for them. Secondly, it is unfair to the astronauts to keep them on because we are blighting careers by keeping them in a fishbowl, doing nothing except swim around and eating Pablum.

Now this certainly should be one of NASA's chief concerns at the present time. With the tremendous increase in reliability, we, therefore, don't have the flights that we expected.

The other point about it is—and I would like you to answer this here by a statement.

Now what have you done about putting woman in space? When is our first woman astronaut, with all your brain team down there, going to go up?

Mr. HECHLER. You are asking Mr. Harper to answer that?

Mr. FULTON. He is part of the brain team and he may be able to give us some enlightenment. He is projecting. I am extrapolating a little bit and pretty much postulating.

Mr. HECHLER. We had Dr. Paine before the committee earlier. It would be more appropriate for him to answer.

Mr. FULTON. I thought the brain team might be better, because we already asked Dr. Paine about this and he sidestepped this.

Mr. HECHLER. There are many brains here.

Mr. FULTON. Dr. Paine has a very good ability not to answer directly. I am moving down the ladder and I am talking about the brain team here.

Mr. HECHLER. The Chair won't dispute any further and give an opportunity for Mr. Harper to say whatever he wants to.

Mr. HARPER. Mr. Fulton, I am afraid I will have to defer that question to Dr. Paine.

Mr. FULTON. I am right back where I started from.

Mr. HARPER. I am afraid my authority doesn't extend out of the atmosphere to discuss NASA plans.

Mr. FULTON. Well, if we are going to treat this particular subject as separately, are we just going to be compartmentising the atmosphere and then space? Are we going to be drawing you fellows all together in NASA? I may be wrong, but I thought this was going to be a general pointing of how you fitted into NASA. But I thought you were a good target, I must say. That is all, Mr. Chairman.

Mr. HECHLER. Mr. Harper, do you know what the budget of NACA was the last full year they were in operation?

Mr. HARPER. I believe it was about $50 million. I am not sure I have the exact figure.

Mr. HECHLER. I didn't hear.

Mr. HARPER. The nearest figure for this, Mr. Hechler, is about $55 million, the total aeronautics-related budget of NACA.

Mr. HECHLER. This is only aeronautics; is that correct?

Mr. HARPER. Yes.

Mr. HECHLER. Then there was a great deal of additional amount not dealing with aeronautics?

Mr. HARPER. There was some, but I don't know the total number. We have extracted out the aeronautics part of it, which was the largest.

Mr. HECHLER. Do you think the criticism is fair that NASA is not doing as much proportionately as NACA did? This criticism is frequently leveled at NASA.

Mr. HARPER. If you judge against——

Mr. HECHLER. Considering inflation, also, while you are answering.

Mr. HARPER. Yes; of course. If you compare total efforts, we are now at about the same level we were in people and dollars placed on R. & D. as we were at the end of the NACA period. It is quite a difference in absolute dollars, but if you adjust this for inflation, it is about the same level of effort in dollars and above the same number of people.

Mr. HECHLER. Then I would say we are far behind, because the problems have not stood still.

Mr. HARPER. Yes. The difficulty I think stems from the point you just made as well as a period earlier in NASA's history, when with the national space commitments and with the resources that were available and with the talent that was available there was no option but to use much of the old aeronautics activity to initiate the space program.

Now it has grown back to about that same level in true effectiveness, but as you pointed out it is a much broader field of problems that we have to face now.

Mr. FULTON. Mr. Chairman, I was on the committee then. I believe the last year of NACA appropriation they had $60 million for aeronautical research, and then about $83 million was added on for space to begin, by supplemental appropriation, and then the first real space budget fiscal year 1960 under NASA was $523.6 million.

So the chairman is right in inquiring if it has slipped badly.

Mr. HECHLER. This is the point I was concluding, that in comparison to the emphasis by NACA put with relation to the total problem at that time, NASA is devoting an inferior effort to aeronautics.

Mr. HARPER. Perhaps a lesser effort. We recognize it as a good effort, although perhaps limited.

Perhaps it is fairer, however, to separate the research and technology program of NASA from the operational activity. The space program certainly represents tremendous expenditures in obtaining operating hardware, operating systems, that don't really represent research in the sense we are talking about it in aeronautics or in the Office of Advanced Research and Technology, for that matter, in the space research area. The costs of operating the system are obviously very, very high and it is not quite fair I think to compare this against a research effort.

Mr. HECHLER. All right. This will be my final question. I will give you an opportunity to define what needs to be done. What really needs to be done in this Nation in order to put more emphasis on aeronautics, which all of us realize is necessary?

Mr. HARPER. Perhaps I should say first if I had an answer to that we would have had more emphasis on aeronautics up to this point.

Mr. HECHLER. In your answer, you are not limited by funding or you are not limited by clearances. You have an open-ended opportunity now. I have served you up a very soft pitch and you have an opportunity to give it a clout.

Mr. FULTON. Remember Mr. Fitzgerald, though. [Laughter.]

Mr. HARPER. I think the start toward solving these problems is being taken, Mr. Hechler. One, a critical limitation in the past has been the number of people in our research centers that have been demanded of the space program and were taken from aeronautics to solve space problems, space technical problems. We have now the interest of our center directors raised to a much higher degree in the problems of aeronautics. This is where the greater increase in aeronautical personnel has come recently, transferred back from the space research into aeronautics. At Lewis Research Center alone, which went entirely out of air-breathing propulsion, we have about 250 engineers back in aeronautical research.

We have pointed out, both Dr. Paine and I have pointed out, I think Mr. Lundin did last year, that a very serious limitation is the inability to bring younger engineers into the program. The sophistication of the technology is much higher than it was in the days of NACA and

the training we received—I myself received—in college then is simply not adequate to meet the scientific depths required to understand these problems today. I don't have a solution to that problem. You recognize the limitations in NASA's personnel ceiling that have prevented an increase in new personnel. This is one of the prime objectives of this new agreement with the Army, in which NASA will have the freedom to recruit new college graduates against Army positions assigned to NASA, and we will direct them, their technical activities, in areas of mutual interest to the Army and NASA, of which there are many. This is one attempt to solve this problem.

Another point, of course, that we have discussed at length is that of having the decision made that NASA should carry this advanced research through applied technology and to the very early stages of development. This has not been a clearly accepted policy on a broad scale, although there are several instances of this being done.

For example, you recall in the discussions of the noise program, the question whether NASA should undertake this extension of its advanced research to demonstrate with Boeing & Douglas the effectiveness of acoustic treatment of nacelles, whether it should undertake the very limited development of a research engine that would let us study new principles of noise reduction at the source. I think a definition of the role of NASA in this area would do much to accelerate aeronautical advancements.

Now this study that we keep referring to, the NASA–DOT study, should identify the real value of letting NASA do such work, if there is real value in it, or whether it should be left to the industry. The decision along that line I think would accelerate many of the developments that you are speaking of.

The dollar limitation is not so serious. It is important, but the work of real value from NASA in the aeronautics program comes from in-house work, in-house research, not research that we purchase through industry.

Mr. HECHLER. Well, is there anything else outside of NASA that could or should be done in order to focus more attention on aeronautics in the Nation?

Mr. HARPER. I am afraid, Mr. Hechler, I can't think of anything that we are not trying to do at the moment. The coupling of our work with all the other agencies involved certainly will be a major step forward. This can't be done overnight since I guess you must recognize you are flying in the face of bureaucracy when you try to couple two agencies very closely. But it can and will be done. Dr. Foster in DOD is very insistent on this. Mr. Beggs because of his experience in NASA is very insistent on this being accomplished. We will accomplish it and I think it will serve to accelerate developments much more rapidly if they are done in this joint way.

Mr. HECHLER. I am in favor of and will support anybody who flies in the face of timid bureaucracy, and I hope you utilize some of your most updated aeronautical techniques in making those flights.

Any further questions by members of the subcommittee?

(No response.)

Mr. HECHLER. Or the full committee?

If not——

Mr. FULTON. Might I explain the point I was trying to make? If these astronauts are not to be used in space, the question then comes where can we use them? If they can't be used on aeronautical research, since they are former jet test pilots, because they are not satisfactory, then I think you have a problem of what is their future, and this is where you come in. Thank you, Mr. Chairman.

Mr. HECHLER. Thank you, Mr. Fulton.

We are going to start at 9 a.m. tomorrow with testimony by Mr. Lundin, director of the Lewis Research Center, followed by testimony by Dr. H. Guyford Stever and Dr. Raymond L. Bisplinghoff.

If there is no further business before the subcommittee, we stand adjourned until 9 a.m. tomorrow.

(Whereupon, at this time the committee adjourned, to reconvene at 9 a.m., on Tuesday, December 9, 1969.)

(Additional questions and answers and material for the record is as follows:)

Question 1(a) In 1957, the last year that appropriations were made for NACA, that agency received $117,276,209. This year NASA received $180,000,000 which is within the same general funding areas. In view of the effect of inflation during the past 12 years, this would suggest that NASA's support of aeronautical research has grown little, if any, since NACA days. Do you agree?

Answer. Of the total funding appropriated for NACA in 1957, an analysis shows that approximately $60M of these resources were directed specifically at aeronautics research; the other support was directed at missile and space-related research. Thus, the $186 million level for FY 1970 represents a significant increase in NASA aeronautics-related research.

Question 1(b) Do you believe that the NASA research effort is now sufficient to keep the nation predominant in the aeronautical field?

Answer. NASA aeronautics research alone cannot keep the nation predominant in aeronautics. It will take a joint effort on the part of several agencies as well as industry to accomplish this. NASA is steadily increasing its effort in basic research where its primary responsibility lies; in research beyond this NASA is working closely with other agencies to resolve the mutual degrees of responsibility.

Question. 1(c) One witness testified that initially a 40 percent increase (approximately $70 million) in NASA's aeronautical research program would be required to provide a desirable level of research. How do you view this estimate and what do you think of the prospects of NASA providing additional funds in the future?

Answer. In the coming years some increase in funding for the NASA aeronautical research program will probably be required, but the exact amount is difficult to estimate at any point in time. An increase of approximately $70 million would support some additional proof-of-concept projects, and if such additional funding were made available, these would need to be selected jointly with other government agencies.

Question. 2. In testimony witnesses have stated that on some new aircraft development basic aeronautical data were not available. For example, aerodynamic characteristics of six percent thickness airfoils, and on basic V/STOL information. Historically, NASA has been foremost in providing these types of data.

(a) Would you comment on why and to what degree NASA has not been able to supply these data?

Answer. Aircraft technology is now so wide in scope that it is impractical to attempt to cover all areas in the depth required to provide data for specific aircraft design. NASA attempts to forecast those elements of technology nearest application and provide greater depth in advance. A particular effort is being made to assure NASA a longer lead time so that its program can be adjusted in advance of decisions to provide the data necessary. In many instances this has been done; for example, NASA has provided FAA and industry with a good base of data on which to consider development of STOL aircraft.

Question. 2(b) The Committee has been told that internationally, the United States is gradually losing ground to our foreign competitors, primarily because

of a lack of an aggressive research base normally supplied by the government. How do you view this situation?

Answer. Both the quantity and quality of foreign competition in civil and military aircraft are increasing noticeably. Where the U.S. held an unquestioned lead a few years ago in both fields, foreign competition has made a substantial entrance into some fields, such as a small short-haul passenger and cargo aircraft and small military fighter aircraft, and has placed in competition or has under development a number of highly competitive large transports. This is particularly true of Soviet aircraft, which a few years ago resembled an earlier generation of U.S. aircraft but today are extremely competitive. While these presently lack a world-wide support system, apparently this gap is the focus of a considerable effort to close. Taking the European community as a whole and assessing available information as to Soviet activity, it must be concluded that both are pursuing now an aggressive aeronautics R&D program making available new technology at a pace comparable to the U.S.

This is in substantial contrast to the situation of five to ten years ago. Perhaps the most significant point is the policy, being pursued by both Europeans and Soviets, of converting new technology into prototype or experimental systems. They have produced a surprising number of new experimental engines and airframes which have served to focus research in a way leading to rapid solution of problems and later production of highly successful aircraft. Activity in this phase has been noticeably higher than in the U.S. and has led to small quantity production of several very promising types ("Harrier" VTOL, Breguet 941 for example) which promise the U.S. intensive competition in the near future as the operational value becomes demonstrated.

Question 3. Witnesses have testified that foreign competitors are taking more aircraft designs to prototype development, whereas the United States is falling short in not doing so. Do you think that this is a logical funding area for NASA, particularly in view of apparent future de-emphasis in DOD?

Answer. As indicated in the answer to question 2(b), foreign nations have accelerated their prototype activity, which is a principal method of closing the gap between new technology development and application of this technology to operational system. Without this activity the transfer of new technology to operation is much slower. Whether NASA or another agency should carry out or be responsible for these activities depends on the principal objective of a prototype program.

Where the objective is to complete assessment of a new technology, that is, to obtain that knowledge which can be found only through limited operation or to uncover the "unknown-unknowns," it would be appropriate for NASA to take the initiative as it is necessary, in many instances, to complete its mission. Prototypes which are developed to near-production refinement for purposes of determining readines for production, or compatability with established systems (airports, airways, logistics, etc.) would be best handled by an agency responsible for final operation (DOT or DOD). Between these two extemes lie cases where both objectives can be served; these should be handled on a joint agency basis. It is difficult, therefore, to generalize on specific agency responsibilities on other than a case-by-case basis. It is important in national rationale, however, that care be taken to assure the activity be pursued at a proper level and not be overlooked simply because an over-all assignment of responsibility cannot be met.

Question 4. Testimony has revealed that DOT is the department with prime leadership responsibility for aviation in the executive branch, yet they are not a member of the Aeronautics and Space Council. Do you believe that membership for DOT is desirable?

Answer. In a consideration of aviation matters by the National Aeronautics and Space Council, participation by DOT would be useful in our view. Because of the membership of the National Aeronautics and Space Council involves the organization of the Executive Office of the President we would defer to this Office on the question of whether formal membership of DOT on the Council is desirable.

Question 5. The Aeronautics and Space Engineering Board of the National Academy of Engineering published in December 1968 the results of their study on various subjects in the aviation field.

(a) What value have these studies been to NASA?

Answer. A primary value of the ASEB study to NASA was an independent assessment of the aviation problems facing the country. This provided the opportunity to provide an unbiased framework against which to judge NASA program content.

(*b*) *What actions have occurred as a result of these studies?*

Answer. To a large degree NASA's program was found to be responsive to the ASEB recommendations and some shift in emphasis was made to bring greater conformity. Some new research activities were added and a few de-emphasized or discontinued. As Dr. Stever noted in his testimony given during these hearings, of the 100 recommendations made by the ASEB, 81 related to NASA programs. Of this group of 81, NASA had responded to all but 15; no response could be made to the 15 because of either unavailability of appropriate technical personnel or of funds.

Question 6. Prior testimony before this Committee has always indicated that we need more money for research, better cooperation between agencies and more time to solve problems. Yet each year we get about the same request for funds from NASA, we seem to have the same problems of too much traffic, increased delays in aviation transportation. What do you foresee as the budgeting trend in NASA?

Answer 1. Since 1962 the total NASA aeronautics effort has increased steadily, rising from $44M in '62 to $185.6M in '70; even allowing for a loss in dollar value, this represents a significant increase. Without question, the related problems have increased in magnitude and scope more rapidly. Although a continued growth in NASA's aeronautics effort is expected, a joint effort on the part of several agencies and industry will be required to effectively attack the evident problems. The exact nature of NASA's requirements to meet its share of responsibilities is the subject of continuing discussions between the agencies. A true assessment of the effort toward solution of aviation problems must include the activities of each of these agencies.

Question 7. In what priority do you place the problems in aviation?

Answer. (A) Continued improvement of subsonic jet transport aircraft and its systems to meet rapidly increasing demands—

(a) Improve air traffic control system to relieve congestion and increase safety margins.

(b) Improve airport and terminal area operation; increase ease of aircraft handling and reduce landing speeds.

(c) Improve ground traffic flow in and out of and around airports.

(d) Reduce pollution (noise and smoke).

(e) Improve productivity of aircraft through increased cruise performance.

(B) Bring STOL aircraft to operational status and improve rotary wing vehicles.

(a) Develop technology for improved STOL performance.

(b) Provide data for FAA to establish STOL certification standards.

(c) Define acceptable noise levels and technology to meet them.

(C) Develop a successful American SST and bring it into operational status.

(D) Improve safety and reliability of general aviation aircraft.

Question 8. How do you see the NASA role in supporting research to solve these problems?

Answer. The NASA role is to provide a strong advanced research program to provide the technology to be applied and utilized by DOT, DOD, and the industry to meet the requirements of military and civil aviation. NASA's role would also include selected flight research programs of promising concepts as required to adequately support the objectives and goals of the user agencies and industry.

Question 9a. With the jumbo jets and the SST aircraft coming into commercial transport use, in what direction do you recommend that the NASA aeronautical research programs be directed for the future?

Answer. (1) NASA should direct research effort to provide means of shortening runway requirements of transport aircraft and to increase the airport acceptability rate while at the same time making the aircraft easier to handle and safer on approach and landing.

(2) NASA should direct research effort to provide advanced technology for improved air traffic control to provide the FAA with technology required to define and develop a system from possible options that will be capable of handing the future increased air traffic that will involve a complex mix of aircraft including the jumbo jets, the SST's and V/STOL aircraft.

(3) NASA should direct a concerted research effort to make STOL aircraft and rotary wing aircraft practical for commercial short-haul use in the near future, and should aim for making VTOL aircraft practical for military application first and commercial use later.

(4) Effort should be directed to improving the safety and reliability of general aviation aircraft.

(5) Effort will be directed to responding to the needs of the DOT in the development of the SST, and to providing the technology for a second generation advanced SST.

(6) Research effort in the fundamental disciplines should be emphasized to provide the basic technology to develop new conceptual ideas to apply to the areas outlined above, including research into the fundamentals of noise generation. Such advanced research effort is of equal priority to any of the areas listed and must be conducted on a continuing basis.

Question 9b. Should we aim for hypersonic aircraft and ramjet propulsion or are we too early for the next phase of practical application of this technology?

Answer. It is to early to plan application of technology to a practical hypersonic cruise aircraft; the fundamentals of hypersonic aerodynamics, propulsion for hypersonic vehicles and materials and structures need much more research. However, to provide the technology so that practical vehicles can be considered in the future, research in the various disciplines should be continued.

Question 9c. Is the answer in consonance with the converging progress of space vehicles and air-breathing vehicles?

Answer. There are important differences between space vehicles and hypersonic transport aircraft as now defined. The space vehicles being considered now will not use or require ramjet propulsion—the only requirement is an air-breathing engine for landing and "go-around" capability for short periods of time; this, of course, applies to the space vehicle as currently defined. The structures required may be short-time high-heat type with low total heat load whereas the transport vehicle may be a long-time heat-soaked structure that must have long life for many flights on an economical basis and be as reliable as today's jet transports. The configuration of the cruise vehicle must be such as to provide efficient economics and possess good flying characteristics for commercial pilots as contrasted to space vehicles that only spend a few minutes per flight in the atmosphere and will be flown by highly trained specialist pilots.

Question 10. It is noted that of the $4.7 billion budget asked for by NASA for FY 1970 only about $180 million was directly related to aeronautics. Does an allocation of less than five percent of NASA's budget to aeronautics represent a division between space and aeronautics which will continue into the future?

Note: The approximately $180 million consists of the aeronautical vehicles line item in R&D along with about $22 million in other R&D areas, plus about $80 million of in-house work in the R&PM category.

Answer. $186M is a proper assessment of the level of resources assigned to aeronautics R&D by NASA. The aeronautics R&D budget is justified on its own merits within NASA and particularly within OART. There is no reason to expect a fixed relation between space and aeronautics funding, although clearly the magnitude of the overall budget affects the degree to which the aeronautics R&D program proposals can be accepted by NASA.

Question 11. Press reports indicate that the Administration has set a timetable for development of a long-range national program for civil aeronautics R&D. Additionally, it was reported in September that a DOT–NASA group is "getting off the ground" in a study of how much R&D in civil aviation the Government should do. From the respective management levels assigned to the Space Task Group and the group for aeronautics study, it might be concluded that aeronautics is much lower in priority and needed emphasis than the space program.

(*a*) *Is this an accurate conclusion?*

(*b*) *What are the respective levels of effort in aeronautics in the three options included in the NASA Report to the President's Space Task Group?*

(*c*) *It is noted that only in Option I does NASA indicate an increase in aeronautical research. Is this in keeping with all the testimony indicating an increased need?*

(*d*) *Is this consistent with the answer to Question 1 above?*

Answer. Answering the several parts of the question:

(a) Since the DOT/NASA study reports to the Secretary of DOT, and Administrator of NASA, it should be concluded that highest management is involved. Decisions on national space commitments, however, required an immediacy of action on major decisions not present in the aeronautics case.

(b) The President requested the Space Task Group to review the national space program. In its early deliberations, the STG considered inclusion of aeronautics in its activities, but decided that it was best to concentrate on the complex issues presented by the space program. In presenting cost projections

for NASA, an assumed level for aeronautics was included to give an overall estimate, but without any intention to indicate study of or conclusions regarding specific future requirements for aeronautics.

(c) As noted above, none of the three options included predicted estimates but rather representative or assumed levels. Option I did specify an increase in aeronautics R&D to conduct major proof-of-concept programs.

(d) In view of the fact that the Space Task Group did not attempt to specify future requirements in aeronautics R&D, there is a need to further consider these future requirements in the NASA/DOT study.

Question 12. It is noted that NASA apparently is increasingly involved in aircraft navigation, air traffic control systems and safety of flight devices. Yet, the FAA is largely responsible for system development of the SST and for the airways structure. It would appear this represents a mix-up of agency responsibilities. Will the delineation of responsibilities among executive departments be examined as part of the Administration's look at a long-range national program?

Answer. NASA is involved in conducting research and developing new technology to solve problems in the areas cited. FAA is concerned principally with the development and application of devices in the technical areas cited which would lead to a total system best serving the nation's needs. If the distinction is made in this way the agency responsibilities are largely consistent. The phasing from research through to application involves joint interests at some point, and the direction of research requires guidance from the ultimate user. These particular interactions are under specific discussion between DOT and NASA at the direction of the Secretary's (DOT) and Administrator's (NASA) offices, respectively.

Question 13. A prior industry witness raised an interesting point on NASA's acceptance of a proliferation of research projects in their role of a supporting R&D agency, rather than continuing their effort to their demonstrated competence in established disciplines.

(a) Do you see a trend developing in this direction?

(b) How does NASA participate in planning the overall research effort that is pursued?

(c) Does NASA need new facilities or have new tasks placed on them dictated the need for new facilities which may be limited in research applicability?

(d) Will the NASA-DOT study specifically include recommendations on V/STOL problems?

(e) To what extent does the problem of lack of data, as stated by the AIA witness (need for high Reynolds Number wind tunnel, need for aerodynamic data on airfoils of small thickness and structural data) exist for your forecast of future aircraft development?

Answer. When NASA is in a supporting role to another agency it is seldom engaged in research but, rather, involved in defining solutions to engineering problems uncovered during system development. Although these individual activities may appear unrelated to NASA's research they do relate to specific disciplines in which NASA has competence. To the best of its ability, NASA uses these "problem-solving" exercises to contribute to basic technology and prevent reappearance of the problem in a slightly different form.

(a) Undoubtedly these demands will increase for, as aircraft become more sophisticated, some problems will not surface until development is well underway.

(b) In planning the "research" (or development testing involved), NASA works with the requesting group to minimize the effort directed at solving the specific problem and maximize the effort useful for solution of the general class of problem.

(c) There are clearly defined requirements for major new research facilities if the risk of soaring development costs is to be kept low. Often the need for new facilities is emphasized by requests to help solve developmental problems in facilities which did not uncover the problems at an early stage. Obviously, the existence of these problems is symptomatic of a technical ignorance which would justify research effort. Thus a facility built to solve a specific problem would almost certainly be used to conduct research on the problem in generalized form so that it could be avoided in future developments. Almost without exception, a facility built to study one special problem has proved to be useful in much wider and unexpected areas of research.

(d) The short-haul air transport system will form one important element of the DOT/NASA study and V/STOL aircraft will be included in this.

(e) The lack of these data for the purpose of *forecasting* probable aircraft development is not serious, except where the data might have revealed a wholly unexpected physical phenomenon. For *forecasting* purposes it is reasonable to make assumptions, based on good judgment, as to probable technical advances. This is not adequate, however, when serious consideration is to be given development. Very small changes in many characteristics can make the difference between success or failure. At this stage the lack of detailed data could prevent development, force a very conservative approach, or court development disaster.

Question 14. How do you react to the statement that more prototype development is needed by Government Agencies to keep the United States abreast of world developments?

Answer. There is no question but that prototype development is the most certain way of defining the best developmental lines to follow and enables development to proceed rapidly with much reduced chance of failure. This is particularly true when the prototype is a system (aircraft, air traffic control, and airports) where several groups are involved. Since other countries are following this course by government support, they are becoming more competitive. Whether this has reached a level justifying similar action within the U.S. is not established. Whether the U.S. requires acceleration of development along certain lines to such an extent that prototypes are required, also is not clear. The DOT/NASA study should define a process by which these decisions can be reached for any instance related to civil aviation.

Question 15. To what extent have the 1968 National Academy of Engineering aeronautical recommendations been incorporated in NASA planning?

Answer. The Aeronautics and Space Engineering Board of the National Academy of Engineering in its report of August 1968 made 100 recommendations for aeronautical research. Of these 19 fell under the jurisdiction of other agencies. Of the remaining 81 recommendations, NASA has work underway on all but 15. NASA has thoroughly reviewed and studied the Board's recommendations and has attempted to respond fully to all of them. In many instances work was already underway at an appropriate level of effort; in some, work underway was expanded. Of the 15 for which work has not been initiated some were considered to be in areas for which the capability and interest exists in the industry to a greater degree than in NASA, e.g., structural fabrication technique, materials joining methods, and lightweight power transmission. NASA has responded to the best of its ability within the limits of the manpower and resources allocated to aeronautical research and continues to review the Board's recommendations along with those from its Research Advisory Committees, and requests for assistance from the DOD and DOT in its program and budget planning.

RECOMMENDATIONS OF THE TRANSPORTATION WORKSHOP

The Transportation Workshop was an ad hoc group which worked intensively for a few months in 1967, under the co-chairmanship of Bernard A. Schriever and William W. Seifort, to make a systems-oriented study of the national air transportation system and its interfacing modes. The competence of the participants in the study and the value of the study results are widely recognized. The study report is used as a primary reference by the Joint DOT-NASA Civil Aviation Research and Development Policy Study.

The report of the Transportation Workshop was printed in 1968 by the MIT Press with the title "Air Transportation 1975 and Beyond: A Systems Approach." This book contains 515 pages of which 50 are used in listing the conclusions and recommendations of the six panels: socioeconomics, air vehicle, air traffic control, airports and terminals, mixed-mode collection and distribution, and government policies.

The conclusions and recommendations of the systems study have been summarized concisely in a essay (The Impending Crisis in Air Transportation) by the co-chairman printed in the Technology Review (April 1968). This essay is attached.

Only two of the panels dealt directly with aeronautical research. The major recommendations of these panels, air vehicle and air traffic control, are given below.

Recommendations of the air vehicle panel[1]

"Almost all the elements supporting air transportation need intensive attention to bring about immediate improvement. Most of these elements have not been keeping pace with either CTOL vehicle technology or the passengers' and shippers' demand for air service.

Integration of these elements and coordination of air transportation with the total transportation system are required. Realistic long-range planning must be intensified and correlated. Effective methods must be developed to identify the most desirable and practicable solutions. The data base to apply these methods must be enlarged and improved in coverage and accuracy.

The evolution of short-haul V/STOL vehicles must be speeded up to match that of CTOL airplanes over the past 30 years. First, studies are required to narrow down the numerous vehicle concepts to the most promising, so that these can be given the benefits of intensive application of technology. Second, after the first step has reached at least a preliminary stage, demonstration projects should be conducted. These projects should be designed to obtain the reliable economic and operational information required by the investors, manufacturers, and operators before they can commit themselves to a full-scale short-haul system.

Recommendations of the Air Traffic Control Panel[2]

Planning:

1. Compile basic information relative to traffic demand.
2. Develop long-range plans and establish interim goals to minimize duplication of spending.
3. Outline organizational approaches that might simplify implementation of advanced technology in air traffic control systems.
4. Initiate a technical plan for the next-generation evolutionary air traffic control system.

Development:

The post-1975 evolutionary system takes into account:

1. Air vehicles with new performance standards.
2. Growing numbers of aircraft, particularly in general aviation.
3. New concepts in types and location of airports.

With these basic concepts in mind, the following recommendations are made:

1. Improve ATC in the terminal area.
2. Initiate immediate long-term evolutionary development of a new more responsive ATC for both en route and terminal areas. The system must adopt advanced technologies, since new types of aircraft will be in service in the coming decades, including the SST (supersonic transport), ASST (advanced supersonic transport), HST (hypersonic transport), and VTOL (vertical takeoff and landing). Complicating the introduction of these aircraft will be the large numbers of all types of aircraft that will be in operation. Forecasts indicate a continuing increase in quantities of both passenger and cargo aircraft through 1990.
3. Live on-site test programs should be undertaken by DOT/FAA so that improvements can be verified prior to integrating the new system throughout the ATC network. Such programs should include:

   Test operations of VTOL aircraft in the ATC terminal area environment.

   Experiments with systems permitting expedited movement of equipment at the airport complex, particularly under poor visibility conditions.

   Experiments with noise-abatement revisions so that increased air traffic can be measured.
4. The measurement and short-period prediction of weather in the terminal area and the communication of realtime weather information between the weather system and the ATC system should be improved.

Funding:

Future funding criteria and policy for ATC and meteorological facilities should be established.

[1] Air Transportation 1975 and Beyond: A Systems Approach, p. 264.
[2] Ibid., pp. 333–335.

Technology:

Mechanisms should be developed to introduce advances in technology into the ATC system in an orderly fashion.

Standardization:

Further ATC standardization of codes, abbreviations, and system interfaces should be developed and accepted by all countries. Continued ATA, ICAO, and IATA activities in this area are encouraged. It is recommended that one United States government agency be responsible for standardization in the United States. Strong support must be given to accelerate time-consuming standardization activities in order that equipment developments can proceed.

Training:

Planning for ATC training programs in the United States should be a joint effort of FAA and ATCA (Air Traffic Controllers Association).

Summary:

Policies and organizational arrangements should be established that will provide a means for continuous systems studies, reviews, and recommendations; a dynamic evolutionary air traffic control system will result.

Utopia does not lie ahead. But partial solutions embraced at once will permit total planning to stem the tide of congestion

Bernard A. Schriever
and
William W. Seifert, Sc.D.'51

ATTACHMENT

The Impending Crisis in Air Transportation

The people of the United States enjoy a personal mobility unmatched anywhere in the world, a freedom of movement regarded as a right and not a privilege. It is a social value woven deeply into our lives. The freedom to travel and to trade without barriers is the basis of the mass production and marketing that have given us the highest standard of living man has known.

But unless we begin now to take steps to meet the demands of the future, sheer growth in population and the accompanying economic demands could so saturate our transportation system, especially the air system, that mobility could become a premium service instead of a routine accommodation.

In 1966 air transportation accounted for 66 per cent of common carrier passenger miles, as compared to 13 per cent in 1950.

Many factors will further stimulate the growth of air transport. Gross national product, disposable income, and employment are increasing. A new generation of even more economical, high-payload aircraft is coming into service. More people will have more leisure time; some of it will be used for travel. The number of retired persons will increase, and they will wish to travel more. A higher percentage of our population will be more highly educated, and past experience shows that as level of education increases, so does the tendency to travel. Many people in today's travel market still cling to an old-fashioned fear of flying, which helps account for the fact that, as of 1964, only 39 per cent of Americans had ever taken a trip by air. The generations coming into the air travel market will not bring a fear of flying with them, and this will expand the market even further.

These factors of growth lend credence to median forecasts that by 1980 the number of domestic revenue passengers carried by airlines will be four times more than current levels and that air cargo will grow as much as 10 times.

Some Inhibitions to Growth

But serious hurdles face those who are charged with preparing the facilities on which this growth will depend. Any casual air traveler or shipper recognizes signs of trouble in the delays and congestion that have today become the norm. Up until now, the growth of air travel has been relatively unhampered by capacity restrictions, but these favorable conditions are fading rapidly. The factors that may do most to limit the ability of the air transportation system to meet demand are the most difficult to evaluate and to correct.

Most of our hub airports are reaching a saturation point, and saturation equates with costly delays—costly in terms of the ill will of inconvenienced passengers and costly in operating losses to airlines. The Air Transport Association estimated the direct cost of operating delays in 1965 at $41 million, no small economic drain yet relatively insignificant when compared to the potential delay costs in the coming decades. Serious new problems will be introduced when the large subsonic jets and the supersonic transports are introduced into the inventory. Estimates indicate that by 1975 20 aircraft of the C-5, B-747, or SST type will land or depart within one hour at primary airports during peak times. This indicates a need to accommodate up to 10,000 passengers per hour at these locations.

In 1965, 21 major metropolitan areas accounted for 66 per cent of the total airline passenger enplanements and 48 per cent of all air carrier operations at U.S. airports. As a group, these large hubs have, over the years, increased their share of the total U.S. air traffic for both air carrier and general aviation activities. This trend is forecast to continue. Projections indicate that by 1980 these hub airports will account for approximately 70 per cent of all U.S. enplaning passengers.

In 1965 only three large hubs, New York, Chicago, and Los Angeles, generated more than 6,000,000 enplaned passengers each. By 1980, 20 of the large hubs will generate this number annually, according

to F.A.A. forecasts. The number of air carrier operations will also increase markedly, but, because of the shift to larger aircraft, these increases will not be proportionate to the gains in passenger volume. Between 1965 and 1980, air carrier operations at the 21 major hubs are expected to increase 143 per cent and passenger enplanements 444 per cent.

For example, in 1965 the seven airports that form the Miami hub accounted for about three million enplaned passengers. By 1980 airports in the Miami area must be ready to handle nearly 19 million enplaning passengers. To accommodate this growth, Miami will need five times the total air carrier terminal space it has now. It will also require four times the amount of apron area for carrier aircraft, four times the present cargo building space, and six times the amount of existing cargo apron area. The projections for the other large hubs are similarly dramatic. F.A.A. forecasts indicate that the New York hub's present 4,213,000 square feet of gross terminal area (including the expansion at Newark) must grow to 8,864,000 square feet plus 500,000 square feet for international travelers; Chicago's 1,788,000 square feet will have to expand to 6,792,000; and Atlanta will have to find ways and means to build 2,375,000 extra square feet of terminal building to process its forecast traffic.

Similar requirements exist for all the major hub areas—a fact that indicates the extent of the terminals' portion of the problem. The airports themselves face comparable problems and must be expanded to accommodate the larger number and size of aircraft, turning these expensive machines around quickly for departure with fuel, maintenance, passengers, and cargo. The prospects for moving passengers and cargo to and from airports through urban distribution systems that are becoming less adequate each year are even more dismal. (Today not a single hub airport is directly connected to the central city by a fast subway or railroad system.) And there is also the problem of how to control the growing numbers of aircraft that will be occupying the airspace, including takeoff, routing, and landing, within acceptable standards of safety, noise, and pollution.

It is difficult to predict what will finally limit the capacity of individual airports. It could be airport access and egress. It could be the ability of the air traffic control system to handle arrivals and departures. It could be the terminals themselves—the number of people that can flow through them in a given period. It could be the ground-handling facilities for airplanes. A recent study by the General Manager of Los Angeles International Airport indicates that this airport's capacity will finally be limited not by terminal, runway, ramp, or parking facilities but by the capacity of the external road system that brings passengers and cargo to the airport and carries them away. Each airport is unique; each has unique problems. But delays at any major airport back up to cause system-wide delays as equipment fails to arrive on time and schedules deteriorate.

One factor threatening to limit air transportation system growth is paradoxical. General aviation—the air taxis, fixed-based operators, company and private airplanes that play a key role in supporting the industrial and service bases that make our air transportation system possible—is growing so rapidly that it, alone, will absorb anything short of extraordinary future expansion of air traffic control and ground-handling facilities. In 1966 general aviation accounted for 16.2 million aircraft operations at airports with F.A.A. traffic control services, as against 8.2 million commercial operations. The F.A.A. forecasts that by 1977 general aviation will generate 54.9 million operations, as compared to the carriers' 16.9 million. By 1980 the scheduled air carriers' 3,600 aircraft will have to vie for air and airport space with 210,000 general aviation aircraft, more than double today's fleet.

It was the jet engine that made large and efficient aircraft possible, and we are committed to it until another form of propulsion is invented. Jet engines, unfortunately, make noise. No solution to the noise problem is yet in sight. Jet engines also pollute the air. Fortunately, this pollution is not as serious as would appear from the smoke trails left by jets, but it is serious enough to make people complain. As antipollution devices become more common and begin to reduce the pollution from such offenders as cars and factories, the atmospheric pollution contributed by today's aircraft will assume a proportion of the total that will attract increased attention. Noise and pollution will lend pressure—emotional but perhaps unbearable pressure—to move airports farther from our cities. They will force the imposition of noise-abatement flight procedures which are even more restrictive than the ones that are already shrinking critical airspace and raising operating costs. Financing the building of new airports is going to offer a major challenge if noise and pollution force the issue.

Locating suitable real estate is going to present another problem. An important inhibition to growth is indicated by the comment that on a clear day from the top of the Empire State Building one can see 1300 separate political jurisdictions. When a community is forced by congestion to the decision to build a new airport, that new airport will most probably have to be built on land belonging to another community. Roads and other access sys-

tems to the new airport will generally have to cross real estate controlled by several other communities. The resulting jurisdictional problems can create years of delay before concrete is poured, and they can force compromises that must inevitably result in less-than-optimum facilities. The delays occur as a function of local prerogative. The compromises are a consequence of the fact that airport planners employ criteria that differ from those used by urban and highway planners, and planning for these seemingly diverse but actually interrelated ends is being conducted for the most part by men working in isolation from each other. Taken together, these problems may completely block the building of badly needed new facilities.

By far the most difficult growth constraint facing the air transportation system is that of financing. At a point in time when U.S. airlines are committed to the purchase of $10.5 billion in new equipment through 1971, austerity programs are forcing adoption of a federal fiscal policy that passes to the users the responsibility for paying for a greater share of the system. The airlines have been told, in effect, to make the service fit existing fiscal policy rather than to expect fiscal policy to evolve to permit development of the desired service. This policy portends inadequate traffic control facilities and overburdened controllers. New airports, improvements to airports and new access systems must be planned against lowered federal assistance. Because the crisis is so near and the lead times for constructing new facilities so long, austerity measures could not have come at a worse time for the air transportation system.

Clearly, no one yet knows specifically what steps should be taken to optimize the performance of our air transportation system while adequately protecting other segments of society in the face of this impending crisis composed of so many contributory factors. But it is nonetheless possible to outline some system-oriented options for the planner and some recommendations for further study.

The Airport Problem

The projected increases in air passenger traffic lead one to conclude that even if concurrence had been achieved among the jurisdictions involved, if plans had been approved, and if financing were in hand, new terminal facilities could still not be constructed soon enough to forestall peak-hour congestion of epic proportions. Consequently, the near-term solution must be found in increasing the flow of passengers through today's facilities and along the access routes to them. Fortunately, considerable early relief is available, although achieving it will require abandonment of traditional ways of processing passengers.

Co-ordinated, system-wide adoption of automated ticketing and baggage processing, which are within the present state-of-the-art, would go far toward eliminating a major bottleneck in passenger flow through terminals. This in itself would offer relief, but if such a system were incorporated in a complex of passenger-processing satellites strategically located within and close to urban complexes, a large part of the terminal congestion problem would disappear and some of the staggering estimates of future terminal space requirements could be modified. Automobiles could be driven to the satellite instead of to the airport. Well-wishers would not have to accompany passengers to the airport or go there to greet them. Transferring the passenger and his baggage from the satellite to the airport could be handled on an evolutionary basis, beginning with standard large-capacity buses, limousines, and taxis. If satellite locations were planned with the airport access problem in mind, such a primitive system could evolve to a ground transit system carrying the passenger to the airport and, in follow-on refinements, bringing him directly to the skin of the aircraft. While such a plan may be distasteful to air travelers who have been conditioned to expect fancier treatment, the alternatives, with their delays and frustrations, may prove to be even more distasteful.

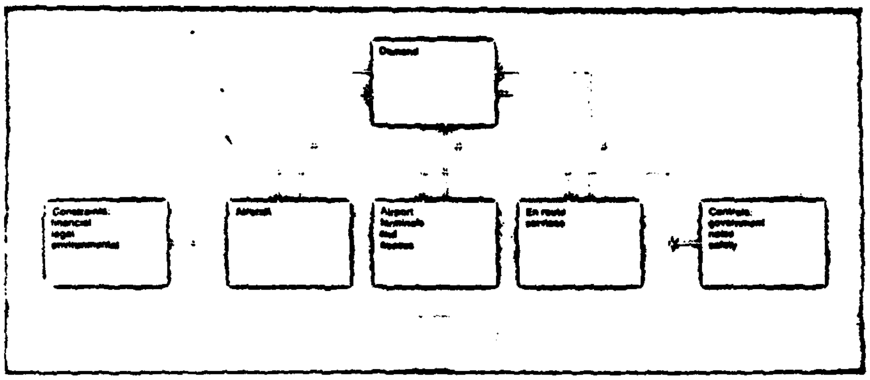
The plan has other advantages. An airport that did not have to devote so much space to classical passenger facilities—ticket counters, circulation areas, concessions, public conveniences, waiting rooms—could then devote more space to its proper business: landing, maneuvering, servicing, and loading airplanes. An airport that did not have to devote so much space to car parking might find room for extra gates, ramps, and taxiways—and in some cases, for a parallel runway that would nearly double the acceptance rate for landings and takeoffs.

Carrying such a plan to its logical end, other typical airport functions could be moved off-airport. This would include cargo-processing functions such as containerization, palletization, and break-bulk operations, as well as heavy aircraft maintenance and overhaul.

Compared to requirements for the construction of new airports, satellite system requirements are not immoderate; satellites could probably be in operation sooner and at lower cost. Adopted as a standard for future airport planning, the satellite plan could end the traditional ways of thinking about airports, which otherwise will continue to create periodic crises in the air transportation system.

Such a plan will undoubtedly run into serious opposition on the grounds that the income from

The diagram below represents the air transportation system as three subsystems—the air vehicle, en route services (airways, navigation, approach control, meteorology, and radiation monitoring), and the airport and terminal with their access and egress systems. The subsystems are interdependent, and deficiencies in one subsystem affect all the rest. The flow of new aircraft into service occurs at a rate that is almost a pure function of marketplace decisions. However, the two supporting subsystems, the en route services and the airport, lag behind. The air transportation system operates in a dynamic environment composed of people and their economy. The burgeoning of population, industry, leisure, education, and disposable income creates new and expanding markets. On the other hand, factors such as noise, pollution, and legal, financial and jurisdictional problems act to restrain their growth. Policy considerations, operating in the public interest, also serve to control demand.



support facilities at airports is necessary to maintain the airport's principal functions; consequently, the development of a system of satellite collection-distribution points will require a new view of airport financing. The satellite plan would also benefit materially from standardization by the major airlines of passenger- and baggage-processing methods, an agreement which may be difficult to obtain in view of the competitive aspects of air travel.

The noise problem associated with the operation of jet aircraft is a difficult one, for a quiet engine is not on the horizon. In time a set of acceptable noise standards will be established, and compatible land-use plans to attract industrial rather than residential development to the periphery of airports will gradually be evolved. These steps and the imposition of restrictive noise abatement aircraft routing procedures will help. Nonetheless, mounting opposition can be expected from those citizens who live within the high-noise patterns of airports. It is clear that we are not going to stop flying, but it is equally clear that we could attach so many penalties to investment in commercial aviation that it would cease to attract investors.

As far as the competition from general aviation for airport facilities is concerned, the solution appears to lie in providing equal but separate facilities for general aviation at reliever airports in hub areas, a solution that takes into account both the traditional freedom to fly and the fact that it is not in the public interest for a private airplane with two persons in it to delay a commercial aircraft carrying perhaps 500 passengers. It also takes into account the fact that, while rising general aviation activity will certainly affect congestion in the air, its major impact on the ground will be felt at only a small percentage of the 10,000 airports in the United States.

Air Traffic Control

If air traffic is to grow with the national economy, the airspace must be treated as a national resource and public funds must be committed. A new traffic control system will have to be developed to augment and perhaps eventually replace the present radar-based system, which will be inadequate for the anticipated traffic. Technology is ready and waiting to computerize and combine the meteorological, navigational, control and communication data fed through the air traffic system; realization

this objective would go far to improve safety and to relieve the nerve-wracking burden shouldered by air traffic controllers.

A decision to require general aviation aircraft to install adequate avionics packages or be *restricted* is obviously difficult to make. Similarly, it is not easy to decide to impose requirements such as *minimum speeds and pilot proficiency standards* on general aviation, yet there seems to be no alternative if we are to avoid unsafe conditions and delays in the airspace. Our system, although recognizing every citizen's right to use the national resources, also contains precedents for restricting that right in the public interest.

Air Freight and Cargo

The rosy forecasts for the growth of air freight and cargo probably disregard a great many hurdles that must be cleared before these levels are attained. Many potential shippers do not understand air logistics as a means of increasing sales and *profits* by enlarging market areas, increasing the length of time perishables and style-obsolescent products *can be on the market, lowering inventory costs,* and reducing the time between shipment and payment. Computer-aided analyses of distribution costs have not been made available to industry and commerce on a sufficient scale. The advantages of containerization have not been made apparent, nor has the requirement to develop containerization that is compatible for all modes.

Spectacular potentials for domestic and world trade are available with the high payload, low ton-mile-cost aircraft that are coming into service. These potentials may be lost unless co-operative planning can reduce the cost of air cargo service, encourage potential shippers to organize for total distribution cost management, standardize containers, reduce the paperwork required for air commerce, and develop suitable air cargo facilities and equipment. This order of planning will demand the combined efforts of shippers, airport operators, air carriers, aircraft manufacturers, and government planners.

Fiscal Policies

Tremendous sums will be required for financing the expansion of airport and terminal facilities, the *introduction of new air traffic control systems,* and the construction of new and improved access means. It is evident that no single sector of the *economy will underwrite these requirements in toto.* It is equally apparent that a systematic approach to financing cannot be developed until data on the *operation of the total system can be assembled and reviewed.* Unfortunately, fiscal operations in the air transport are so fragmented that it is essentially impossible to assemble consistent data. *Furthermore,* estimates of future costs show such divergence that they do not provide an adequate base for decision making.

Future developers will look to the federal and state governments for assistance in the form of grants, loans, and tax incentives. The private investment sectors, and the users too, must assume a share in the financing to ensure that free competition is not replaced by excessive govermental restraint. However, unless and until adequate data are developed and organized, the prospects for articulating an effective fiscal policy are not bright.

Transportation Policy

Utopia does not lie ahead. It is not likely that technology, for all the blessings it may bring, will give us a world free from noise, pollution, traffic jams on the ground and in the air, irate travelers, *jurisdictional quarrels,* or *selfish public and private* interests. Our problems now are taking on a new dimension, with the result that today the crux of *the matter lies not in the realm* of what technology can do but rather in what we want it to do.

One conclusion stands out, unmistakable and incontrovertible. There is an urgent need for organized planning oriented toward the total air transportation system of the future. None of the options can be initiated with confidence without further study to close the gaps in data and knowledge. The options represent at once opportunities and problems. The selection of the best options and the solution of other problems facing the air transportation system argue for immediate initiation of a concerted planning effort. How to organize to do the needed planning becomes a critical target for attention.

This essay is based upon the report of the Co-Chairmen of a Transportation Workshop conducted between June and December, 1967. The full Chairmen's Report is being published this month as the first chapter of *Air Transportation 1975 and Beyond: A Systems Approach,* the full report of the Workshop's many panels, by the M.I.T. *Press.* General Schriever, formerly Commander of the Air Force Research and Development Command and later of the Air Force Systems Command, is President of B. A. Schriever Associates; and Professor Seifert, Assistant Dean of the School of Engineering at M.I.T., is Director of the Institute's Project TRANSPORT.

AERONAUTICAL RESEARCH

TUESDAY, DECEMBER 9, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 9 a.m., in room 2325, Rayburn House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The committee will be in order.

We are pleased to welcome back this morning Bruce T. Lundin, the Director of Lewis Research Center of NASA, and also former Acting Associate Administrator in charge of the Office of Advanced Research and Technology in NASA Headquarters.

Good morning, Mr. Lundin. Glad to have you back. And if you have a prepared statement, you may proceed.

Mr. LUNDIN. Yes, I have, thank you.

STATEMENT OF BRUCE T. LUNDIN, DIRECTOR OF LEWIS RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. LUNDIN. Mr. Chairman and members of the subcommittee, it is a privilege to appear before you once again, and I am grateful for this opportunity to participate in these hearings on our Nation's aeronautical activities. Considered in its full scope and implications, I believe it is not an overstatement to observe that we are now engaged in our Nation's third period of deep concern and response in aeronautics. While the prior periods of concern were associated with gathering war clouds in Europe, today's challenge to our aeronautical health has the added dimension of the numerous and complex problems of civil aviation—problems arising not from an external threat but born of the remarkable success and rapid progress of air transport. These hearings will surely be an important part of the process of marshaling our national strength and will to assure both our continued military superiority in the air and the economy, safety, and convenience of our civil transportation system.

In spite of the difficulties, we have reason to face the future with confidence. In a way, we've been here before. For those of us who are now old enough to have lived and worked in the NACA laboratories through the 1940's and 1950's, it is satisfying to see so much of our early research embodied in today's aircraft. Every supersonic airplane in the world today bears the mark of the area-rule, or coke-bottle shape, developed by the aerodynamicists of the Langley Research Center. The

transonic compressor and the methods of turbine cooling developed at the Lewis Research Center are found on all of today's jet engines. When I inspected the Concorde airplane in Europe this past summer, I found engine inlet and afterburner designs that were direct descendants of what we were researching in the late forties and early fifties.

The list is long, and I recall these few examples not to prove that we were good, or even to note the rather long period of time required between laboratory research and operational aircraft, but rather to serve as a springboard to an examination of the factors or conditions that were present that enabled so much useful research to be conducted. While it may not have been apparent at the time, in retrospect, at least four factors come to mind that were of importance.

First, we had first-rate facilities in which to work. They were modern, unique in the free world, and well suited to the problems of the day. When NACA first set up shop in 1915, one of the first things they did was build a wind tunnel. Ever since, men of faith and vision in both branches of the Government continued to expand and keep this aeronautical research plant up-to-date. Proof of an economic return, cost-benefit analysis and a prior mission requirements were not the mode of the times. The lesson of this piece of history proves the wisdom of going forward on the judgment of responsible and experienced leaders. While reviewing some documents of the time recently, I came across a statement of the Bureau of the Budget which noted that the value of one set of tests in the 8- by 6-foot tunnel at Lewis, which led to improved afterbodies for the F–102, F–104 and F–106 airplanes, justified the total cost of the facility. That situation is probably true for all of our facilities.

A second factor in our favor at the time was our youth. Most of the people doing the research that led to the rebirth of our aeronautical strength after World War II were in their twenties and thirties. They didn't know what couldn't be done, and were willing to plunge ahead, unafraid of failure. The total atmosphere was one of excitement and creative endeavor. Closely associated with this creative, innovative environment was, thirdly, the independent position of the NACA. Created to serve the technical needs of user agencies or industry, it was, at the same time, free to reach beyond the particular, specific problems of the day and to develop a broader body of knowledge.

Actually, a strong combination of both working on the current problems of user agencies and using this contact with real problems as a base to broader or longer range inquiries developed. Each activity, in turn, served the other. I am convinced that had the NACA depended upon reimbursable funds from other groups for its operation, it would have lost both the continuity of effort and the freedom to reach beyond defined requirements that has produced many of the features of the airplanes that fly today.

A fourth element of strength also arose from the close association with the user groups, with those having responsibility for mission or operational success. The close working relationships, almost to the point of a mutual dependence, that developed between the NACA and the U.S. Air Force provided clear objectives and tangible goals. Applied research needs a focus, and as we sought to find ways to enable airplanes to fly faster, farther or higher—the goals of the day—meaningful research objectives such as less drag, high turbine temperatures or more efficient combustors could be pursued with purpose.

These are some of the political and economic factors which, I believe, enabled the healthy growth and ready application of our technical capabilities. While the world is no longer so simple, we had best take care that we either take them with us into the future or alter them only with great care and deliberation.

But now for the future. Our present aeronautics research program is, of course, a broad one, and it is impossible to know with certainty from just which quarter the big advancements of the next decade will come. But a few main elements seem to stand out that are worthy of mention here.

High on the list is the burgeoning field of avionics. The development of the digital computer, the ability of microelectronics to put it into airborne packages and power requirements, and the operational capabilities developed and demonstrated in our space program will surely change the nature of our future aircraft systems.

Fully integrated control, from a central airborne computer, perhaps talking to a computer on the ground or in orbit, will be in command of all phases and parts of flight. Engine power settings, the operation of flaps and landing gear, the selection of optimum flight paths with regard to traffic, weather or fuel reserves, the control of landing patterns will all be selected and operated in an automatic fashion from a central computer. We do that now with our rockets.

The flightcrew will be relieved of those duties that automation can do better, and will be occupied in selection of programs and in monitoring the whole operation. And, when changes are needed or things go wrong, they will either abort the standard program or take over themselves, much in the manner that Neil Armstrong did on our first lunar landing. These inevitable developments in aviation, based on both our electronic technologies and our experience in space, should contribute much to both the economy and safety of aviation.

I have already alluded to the role of man in the system, and commend to your attention in the years ahead this new field of research. Man is no longer simply the guy who has to operate the machinery, but is very much a part of the total system. What kind of displays are best for him, what makes him tired or confused, how well does he work when under stress or fatigue, how should tasks be divided among a flightcrew are matters of current research that will be of increasing importance. In a way, we know much more about the mechanical parts of the system than we do about the human parts.

Among the most dramatic and, possibly, the most important aspects of this man-machine integration is the role of the flight simulator. Although the flight simulator has been around for quite a while, its power for pilot training was most dramatically demonstrated in our Gemini and Apollo programs. The extensive use of simulators for training in rendezvous, docking or landing on the moon provided an essential part of astronaut training. Almost without exception, everything they experienced for the first time in space was an old familiar scene.

But simulators are also an important research tool for aircraft development. There is being constructed at the Langley Research Center a differential maneuvering simulator in which two different airplane cockpits can be set up such that one may fly in combat with the other. Each pilot will receive a display and operate his airplane in accordance with and in response to the actions of the other. By

giving each one a different kind of airplane to fly—by changing the equations in the computer that connects them—we will be able to evaluate various types of combat aircraft prior to building any hardware or even signing a contract. A simplified version of this type of simulator is being used at Langley to study F-4 and F-111 spin entry problems, and has also been used in evaluating the handling qualities of Langley developed F-15 aircraft configurations.

A pilot also flys by more than what he sees out of the window or on his instrument panel; he also flies very much by the seat of his pants. When an engine fails in an SST, the pilot will respond more to the sudden and large yaw motions of the aircraft than to the readings of his instruments. And so, for the very large and flexible airplanes of the future, we have brought into operation this year at the Ames Research Center a moving base simulator. This research capability is of particular importance in human research and pilot training for large, flexible aircraft in which the motions experienced by the pilot are different from, and even unrelated to, the motion of the center of gravity of the airplane along the flight path.

Pilots who have flown both the DC-8 and this simulator when rigged up with the equations of this airplane are enthusiastic about its value and realism. Airplanes such as the 747, the Concorde, or the American SST are pretty expensive machines to use for pilot training and exploration of safe operating limits. I am therefore very pleased to report that we are now joining forces with the FAA to use this simulator for evaluations of the Concorde airplane.

Another field of research that is always of large importance is that of materials. Although progress in this field has been characteristically slow and steady, several things are now going on that have the promise of a real breakthrough. The main thrust of our program in engine materials is—

(1) Toward lower engine weights through the development of materials of higher strength, higher stiffness, and lower density;

(2) Toward higher engine temperatures through development of high-temperature materials; and

(3) Toward improvements in engine reliability and life by a better understanding of why components fail, better life prediction methods, and the use of materials of better performance.

With regard to high strength materials, two new and promising approaches are—

(1) Alloys produced by forging from prealloyed powder ingots rather than by forging of melted ingots; and

(2) Thermomechanical processing in which mechanical deformation, or coldwork, is used together with precipitation in alloys that may have been strengthened previously by precipitation alone.

The strengthening increase by either powder metallurgy or thermomechanical processing is potentially very large. The ultimate tensile strength of one extruded powder product, known as TAZ 8A, is about 230,000 pounds per square inch, as compared to 130,000 pounds per square inch in the cast condition.

The yield strength of another alloy, U-700, has been shown to be increased from 120,000 pounds per square inch to well over 200,000

pounds per square inch by using the thermomechanical processing. Such increases in the strength of materials will enable us to not only use that much less of them in an engine, but more importantly, will open up entirely new avenues of engine design.

For some engine parts and most airplane parts the stiffness of the material is also of importance. Here, the composites of various fibers embedded in a matrix have large potential. Graphite, boron, and beryllium have a very high modulus, or stiffness, and when embedded in a polymer matrix they can produce a material that has about three times the specific strength and five or six times the specific stiffness of steel, titanium, or aluminum. Of course, problems remain, and there is much yet to be done.

These composite materials are subject to erosion damage, are more sensitive than conventional metals to lightning strikes, and are limited in temperature. As you may have heard the fibers are also expensive, costing several hundred dollars a pound. And yet, I am reminded that it was not too long ago that aluminum cost as much as boron fibers do today—and we are now using aluminum for throwaway beer cans.

A few words are also in order regarding high temperature materials. As one example, a recent analysis by Pratt & Whitney Aircraft indicates that the use of a material that could operate at 110° higher temperature in a turbine would produce a 10-percent increase in aircraft range for one mission and a 30-percent increase for another mission.

But two problems face us as we try to achieve materials that are useful at higher temperatures, the limitations imposed by oxidation resistance and the limitations imposed by strength. One, but by no means the only, approach to oxidation resistance is the development of improved coatings.

Now, most advanced engines use coated materials, typically aluminum diffused into the alloy surface. Our data indicate that these coatings provide an improvement by a factor of 5 to 10 in life, or 50° to 150° in temperature capability over an uncoated material. But at the higher temperatures we wish to operate, the life of the material falls off rapidly.

One piece of recent research using an Fe-Cr-Al-Y alloy is therefore of interest. This alloy is oxidation resistant, but very weak. It has, therefore, been made in the form of sheet and bonded to the strong superalloys, thus providing a protective coating. Recent data show this combination to provide an improvement by a factor of eight in life over the best current aluminide coating.

This brief comment on materials research cannot, of course, touch on more than a small part of the total program, and which I am sure you will be hearing more about in the months ahead. My main purpose in calling it to your attention here today is to note the possibly large improvements that current research in this field offers for the future.

Better materials, materials that are stronger, stiffer, lighter, more enduring and capable of operating at higher temperatures will, of course, be useful everywhere. One field which will especially benefit is that of V/STOL aircraft. Both types of aircraft, VTOL and STOL, can possibly contribute much to relieving many of the transportation problems that beset our large urban centers. But, as I have noted

before this subcommittee on prior occasions, the development of this class of aircraft, particularly the VTOL type, has been frustrated by powerplant weights and by complex control and handling characteristics.

Many of the things now going on in electronics research, or avionics, promise to take care of the control end of it. As for the propulsion system, there are now emerging from the laboratory many new concepts of compressor and turbine design and of advanced combustors which, together with better materials, promise a real step forward.

Although this propulsion research, like much of aeronautical research, is highly technical in scope and detailed in nature, one general characteristic is worthy of note. This characteristic, not present a decade or so ago, is the very high degree of interaction among the engine, the inlet, the exhaust nozzle, and the airframe in which it is installed.

Recent tests of supersonic inlets show that the flow of air through the inlet system may not only be distorted, or uneven, across the duct to the engine, but that it may also oscillate at fairly high frequencies. And when we couple such "shaky" airflow to an actual engine, the engine experiences a compressor stall and may cease to operate.

Because the frequencies of these flow oscillations are fairly high, their presence remained undetected until advanced, high-frequency instrumentation became available; the causes of compressor stall under these conditions remained, until recently, something of a mystery. But now we are on the track to both learning how to design inlet systems capable of producing a smoother flow of air, and to tracing these fluctuations of pressure, temperature, and flow velocity through the various components of the engine to achieve an understanding of the physical processes involved.

This work must, of course, be done with complete, full-scale engines operating under realistically simulated flight conditions. Fortunately, the Air Force has been able to provide us with modern engines for this research and the expansion of the Propulsion System Laboratory of the Lewis Research Center provided by the Congress in 1967 has provided the large test chambers in which they may be installed.

Just as the engine and airframe have now become a tightly integrated system, so also has the complete airplane become an interacting component of a total transportation system. No longer is the best airplane the one that flies farther, faster, and higher, or even more quietly, safer, or economically. It must also fly in a manner that is at least compatible with, and preferably in an optimum combination with, the air traffic control system.

Conversely, the design and operation of our future air traffic system must be compatible with the characteristics of our future aircraft. Even the runway acceptance rate, the handling of the airplane on the ground and of its passengers, cargo, and servicing, must be treated as a whole.

These problems are obviously as complex as they are important. To affect solutions here, we will need both new, complex and expensive research facilities capable of dealing with big system problems and new working relationships and political arrangements among the several agencies of the Government and industry who are inescapably involved.

As one final comment about the technical nature of the years ahead, I would note the possibility of increased interest in the transonic-speed range, or in the range from mach 0.7 to mach 1.4. The cruise speeds of commerical and military transports have already reached about mach 0.85, and further increases to about mach 1.15 are of interest because this speed can be attained without sonic boom effects.

The transonic speed range is also critical for a supersonic transport because performance in this range determines subsonic cruise efficiency. Transonic speed characteristics are important to fighter aircraft because they are required to maneuver at these speeds, and they are important to bomber aircraft because they affect the engine size which is necessary to accelerate to higher supersonic speeds.

And so, I think you will be hearing us talk quite a bit about problems in the transonic range in the years ahead. And there are many problems and difficulties here. It is in this speed range that many interactions, shock waves, and flow separations occur that become important to the thrust, drag, and stall margin of the engine and on the lift, drag, and buffet characteristics of the aircraft.

Unfortunately, mathematical prediction techniques do not work well in this speed range, and experimental testing becomes of major importance. But, again unfortunately, the characteristics of transonic tunnels are such that only very small models, of the order of 1 or 2 percent of the tunnel throat size, may be used and scaling up results from very small models to full size airplanes is at best difficult and usually impossible. We will be paced here for some time to come by the capabilities of our experimental facilities.

But tough as all these problems may be, we can, as I noted at the outset, face the future with confidence because we do have a number of things going for us. In the first place, we are and will continue to reap many benefits from our space technology program. Not only will the control, navigation, and communications aspects of aeronautics benefit in a fairly direct manner from space activities, but the broader technologies of materials, electronic components, power systems, man-machine integration, and many other space-borne technologies add to our aeronautical strength.

We also have modern high-speed computers for problem solving, advanced instrumentation and methods of data handling, and a whole array of management and communication skills that were not present a few years ago. And we do have today, in place and at work, a total force of some 5,000 men and women in NASA engaged in aeronautical research. Their work is, for the most part, quite good; we are aware of the problems and are, I believe, responsive to the needs, both short and long range, of the responsible user agencies. This is, perhaps, our greatest asset.

But recognizing our problems and assessing our strengths is not enough. We must also marshal and manage these resources to meet the new problems. In so doing, I suggest that at least the following six points, arranged not in any order of priority, be on our agenda for the future.

For one, we must give impetus to the long process of rebuilding our aeronautical research facilities. During this past decade, some $35 million have been invested in the aeronautical facilities of NASA, as compared to a total of $169 million in the preceding decade. Just what these future research facilities should be is, for the most part, for

others to determine. I would suggest, however, that some of the main elements include facilities to conduct research on large-scale total, interacting systems, in the new field of avionics, on research dealing with man-machine integration, and on the transonic speed regime.

Also, the difficult gap that always seems to exist between research and development must be given constant attention. Technology that isn't used is no good, and a new system development that isn't based on sound technology is destined to fail. We should, I believe, concentrate a little more on doing and a little less on studies. We should not be afraid to build experimental hardware just because a need isn't proven or because it might not succeed.

Efforts to close this gap between research and system development has sometimes been identified as a proof of concept activity or in the building of demonstrator hardware. Neither term properly fits the situation. Rather than simply prove that a concept is correct or to demonstrate a capability to skeptical users, what is really needed is experimental hardware to complete a technology development or to evaluate a new operational concept before a major system development is undertaken.

A typical example of such experimental hardware is found, I believe, in our quiet engine project at the Lewis Research Center. Here we are not building a complete engine, or even a prototype of a production engine, but are building fullscale experimental hardware in order to identify in an authoritative way the technologies required to build quiet engines. This provides us both with engine design rules for possible future aircraft engines, and will provide the Department of Transportation with authoritative technical data on which they may with confidence base future noise regulations.

Another gap that must be filled is the descreasing fallout from military developments into the civil area. No longer can the requirements of our civil aviation system simply follow prior developments in the military sector. I look forward here to the increasing attention in the NASA research program to the problems of civil aviation such as engine noise, aircraft safety, navigation and traffic control, pilot training, etc., and to the emergence of close programmatic and working relationships between the NASA and DOT along the lines that have existed for decades between the NASA and the DOD and their respective predecessor agencies.

In the long run, it is of the utmost importance that the support of the NASA aeronautical research program be kept free from financial dependence on the user agencies or industry. Research is a long-range business, and cannot be conducted with a year by year dependence on someone else's budget. Continuity of effort is more important than higher average budgets obtained through a process of periodic building up and phasing down.

Furthermore, user agencies, with their pressing and important problems of the day, cannot be expected to support or even understand the reach beyond today's problems into the future that is so essential to growth. And finally, those whom we would serve are deserving of an objectivity that can only come from independence of support. The long and successful history of NACA proves the ability of an independently supported agency to respond to the needs of others.

And lastly, a word about our people—our most precious commodity. We have today, as I noted earlier, a work force of some 5,000 men and

women in NASA engaged in the broad field of aeronautical research. This is a strong capability that is producing valuable products, and which is a good base upon which to build. The constantly shrinking R. & P.M. budget, and the virtual hiring freeze that has been necessary at our major research centers is, however, a matter of deep concern.

As I return to our research centers and visit the laboratories where the work is done, I am deeply disturbed by the relatively smaller proportion of young people about. I therefore strongly urge your support of efforts to reinstitute the ability to bring young college graduates into our centers. While the funds required are relatively small, we are getting close to reaping the bitter fruits of an aging research organization. The loss of a proper skill mix that is imposed by such personnel limitations also results in a degradation or interruption of skills and services that can have far-reaching implications on the total operation of a center.

I am speaking here not of the total level of activity that may be underway at any particular time, but of the long-range strength and vitality of our Federal research laboratories that have served us well for many decades and which are, in many ways, our best hope for the future.

That completes my prepared statement, Mr. Chairman.

Mr. HECHLER. I congratulate you, Mr. Lundin, on an outstanding analysis of the ongoing programs for aeronautical research, and also for posing some of the problems that we are going to confront and have to grapple with in the future.

You mentioned here the age of the 5,000 employees. You may not have figures on this, but I think it would be helpful to have someone in NASA supply us some more specific average age figures which go back a few years—say to 1960, when you probably had less employees—and the age of those employees at that time. I assume they weren't all the same employees.

Mr. LUNDIN. Yes, Mr. Chairman. I would be glad to provide that information for the record, and I would appreciate the opportunity to comment further.

If we simply compare the average age, that is not a true measure of the problem I am concerned with. The average age in our centers now—and it varies from center to center, so I can be only approximate at this moment—is somewhere in the neighborhood of 38 to 40 years.

If we look back to 1960, we may find that it is 3 or 4 years younger than that. But what is giving me even a greater concern than the average age is the absence of young people in their twenties doing research. There is a smaller proportion or percentage of younger people in the laboratories now, that is not fully reflected in computations of average age.

(The material requested is as follows:)

The problem discussed by Mr. Lundin is the inability on the part of NASA in general, and OART in particular, to maintain the inflow of young people into NASA laboratories. This situation results from two principal compounding factors. First is the successive reductions in authorized ceilings, amounting to over 1,000 positions in the last 3 years. Secondly the attrition rate at all Centers has always been modest, and in the last 2 or 3 years only half of that of more normal times. These two factors, in combination, have precluded hiring of special skills and young college graduates into OART Centers.

The most serious aspect of this problem is the absence of young people with special highly needed skills at our Centers. As shown in the attached table, the entrance of college graduates into our Centers has dropped from a

normal value of 179 in 1966 and 165 in 1967 to only 23 last year. As a result, the number of scientists and engineers under the age of 30 has decreased by 200, or nearly 20 percent, within the last 2 years.

The effect of this situation is twofold. In the near future, because of disproportionate separations in some skills categories, the skills balance required for effective operations will be lost. Of even more importance is the inability to bring into the OART organization fresh, new talent that is the life blood of any research group.

New hires of scientists and engineers under 30 years of age

Fiscal year:	
1966	179
1967	165
1968	77
1969	23

OART SCIENTIST AND ENGINEERS UNDER 30

	June 30, 1967	June 30, 1968	June 30, 1969
ARC	123	129	102
ERC	67	81	78
FRC	59	57	50
LRC	409	407	321
LeRC	344	327	268
Total, OART	1,002	1,001	819

Mr. HECHLER. The reservoir is getting depleted, so you look forward to some barren years in some areas?

Mr. LUNDIN. Yes. Another number that might reveal this to you, Mr. Chairman, is that we have, in the five research centers for which I am still responsible as Associate Administrator of OART, traditionally brought into our research centers between 150 and 200 college graduates every year. For the last 2 or 3 years, that inflow of young college graduates has virtually disappeared, so this clearly results in a lack of youth coming into the centers.

Statistics are not available, but I can assure you also that there is the situation that the young people that have come into our centers over the past 5 or 6 years, particularly in the period from 1960 to 1965, have tended to go into more of the space-oriented than the aeronautically-oriented activity, because in those years, 1960–65, the space technology was, of course, the more attractive field for young people.

Mr. HECHLER. Well, we are going to explore this subject in a little more depth with Dr. Stever and Dr. Bisplinghoff. Any data that you can supply that would enable us to pin down both the problem and the effects of the problem, and the future of what the problem is likely to be and what could be done about it, would be extremely helpful to the committee.

Mr. LUNDIN. I would be pleased to do that.

Mr. HECHLER. I hope you will supply that for the record.

How many centers are now working on aeronautics?

Mr. LUNDIN. For the most part, five. Lewis, Langley, Ames, Flight and Electronics Research Center. Some specialized or selected work identified as aeronautics is going on at the Marshall Space Flight Center, and the Manned Spacecraft Center in Houston. But it is where they have special selected skills, rather than a broadly based program.

Mr. HECHLER. Are there any advantages or disadvantages in centralizing this work?

Mr. LUNDIN. Yes, and it depends on what we mean by "centralize." Each center has, and I believe strongly needs, what I sometimes call a pole to rally round, a central area of responsibility, so that everybody in the center, from the center director on down to the working people at the bench feel "this is my responsibility and area of expertise, this is where my agency and my country is counting on me."

For instance, Lewis is traditionally, and we feel very much that we are, a propulsion center. Work in aerodynamics is the strong point at both Ames and Langley. Simultators, as I mentioned, are at both Ames and Langley. High temperature materials at Lewis and structure at Langley. We look to Ames and to our center in Houston, the Manned Spacecraft Center, for research in human factors, the Electronics Research Center for the centralized electronic activities.

So each center tends to have a major technical pole to rally round, and in that sense it is centralized.

An increasing trend, and a matter that we have given our attention to quite a bit recently here at headquarters, however, is how the different centers must relate and coordinate their activities, because as I mentioned, we are no longer dealing with separate pieces. It is quite highly integrated.

For instance, we have engine and inlet work going on at Lewis now that is a common program with engine inlet flight characteristics and flight testing at our Flight Research Center, on the F-111 airplane. This is more and more typical of the different centers, where they have to join into a total system view, each contributing from their area of expertise.

Mr. HECHLER. I have just one more question before I yield to other members of the committee.

I have expressed in this committee what I think is the need for an expression of national aeronautics and aviation policy, at the highest level. If such a policy were expressed, what effect would it have on the work at these five centers? Would there be any advantages or disadvantages for NASA's work if such a policy were formulated?

Mr. LUNDIN. I guess, Mr. Chairman, that would depend on what the policy turned out to be.

Mr. HECHLER. This gives you a free and open opportunity, then, to give any views you care to.

Mr. LUNDIN. I feel a certain amount of confidence, if I may, Mr. Chairman, in the stability and value of our Federal research laboratories. I think a policy might be helpful in perhaps further clarifying roles and responsibilities among the agencies. That might be a helpful thing for organizing programs for the centers.

Mr. HECHLER. You had a fascinating phrase on page 12, at the top of the page nere, where you say:

> To affect solutions here, we will need both new, complex and expensive research facilities capable of dealing with big system problems and new working relationships and political arrangements among the several agencies of the Government and industry who are inescapably involved.

I didn't realize they had political problems.

Mr. LUNDIN. Yes. I paused a bit before I used the word "political," but I just couldn't find another one more apt. What I had in mind were things such as the AACB, interagency committees and panels, and such relationships among agencies.

We have many of these now between NASA and the Department of Defense, and I see perhaps more of them will be developed in the future between NASA and other agencies. My meaning of the word "political" was joint boards or panels or working relationships of that sort.

Mr. HECHLER. I have several questions which I will defer until I recognize other members of the committee.

Mr. Pelly.

Mr. PELLY. Thank you, Mr. Chairman.

Mr. Lundin, I think I am correct, am I not, that in the main you take satisfaction in your achievements and your activities, and the morale of your organization is high?

Mr. LUNDIN. Yes, sir, I believe it is quite high.

Mr. PELLY. One need that you feel is for additional or updated research facilities?

Mr. LUNDIN. Yes, very definitely. The facilities are the tools that are used by our people, and they need to be continually brought up against and made suitable for the technologies of the future, against the edge of the technology we are dealing with. I have a concern about the much lower rate of building aeronautical research facilities in the past decade than in the previous years.

Mr. PELLY. Is the obsolescence rate of research facilities, then, very high?

Mr. LUNDIN. No, sir. It is not so much obsolescence. We are still using some of the very first facilities we built 10 and 20 or perhaps 30 years ago. They have been continually updated by modification and alteration. But we need facilities that are suited to the new problems ahead, that the current ones cannot deal with.

For instance, as a simple example, at one time all of NACA's wind tunnels were subsonic in character, and in the late 1940's we could see that the new technical area to be engaged in was supersonic flight, so we built supersonic tunnels.

So I call attention to what I feel may be needed future facilities in such areas as avionics or the transonic speed regime. These are areas we are not facilitated adequately to cope with. But our facilities really have an amazing way of refusing to become obsolete.

Mr. PELLY. You mentioned your quiet engine program. Are you satisfied with the progress that is being made in this area?

Mr. LUNDIN. Yes, I am. However, it is a 2½- or 3-year program, in which we have been engaged only the first 6 months. We are ready for the design review of the first designs, and are to be within the next month ready to pick up the option to proceed into hardware fabrication, and I am satisfied with the progress that has been made to date.

Mr. PELLY. You are aware of the 1968 Noise Abatement Control Act, which was passed by Congress in 1968. Are we making progress as certainly indicated by the Congress that we want to make progress in the field of noise control?

Mr. LUNDIN. Yes, sir. Good progress is being made in some areas. For instance, the acoustical treatment for the inlet duct that we did research on at Langley, first in small-scale models and then in proof-of-concept work in airplanes where we made actual measurements in flight.

Different designs of acoustical treatment showed that we can reduce the noise level between 10 and 15 PNDb, and that is a significant reduction in noise. It is equivalent to, say, removing the noise source about three times as far from you.

It is most effective on the landing noise, rather than the takeoff noise. Progress in the jet noise area is currently underway rather intensively, but I don't have such final results to report to you. But there has been progress.

Mr. PELLY. The reason I asked that question is because while I was reading the Congressional Record this morning before breakfast, I noticed one of my colleagues had inserted a statement in the Record which said that after 17 months, since the 1968 passage of the Noise Abatement Control Act, literally nothing has been done to implement the mandate of the act to provide for the control and abatement of aircraft noise and sonic boom.

And I took exception to that, because I feel a great deal has been done.

Mr. LUNDIN. I think you are correct, Mr. Pelly, but I also well understand the impatience. Work on noise within NASA and elsewhere really received its major impetus only 3, perhaps 4 years ago, and it characteristically requires something in the range of 7 to 10 and perhaps 12 years to see the results of the research finding their way into an operating airplane.

Mr. PELLY. Well, this is the point that I was hoping that you would comment on. It seems to me that it does take a long time to translate the progress that is made in the laboratory into the final test that comes with the noise that exists around airports, and with engines.

But I see progress, myself, in my own personal test, which has to do with a 707 that used to fly over my house out near Seattle: and now the 747, at about the same height, I notice a tremendous improvement.

And this all comes from a laboratory investigation and experiment and eventual progress that translates itself into the engine.

I certainly agree with the chairman that you have made a very fine statement here, one that to me certainly indicates, as I said, satisfaction in your achievements in the field in which you are so interested. I certainly appreciated your statement here this morning.

Thank you.

Mr. LUNDIN. Thank you very much, sir.

Mr. HECHLER. Mr. Fulton.

Mr. FULTON. I am glad to have you here. I am sure the chairman appreciates you particularly because of your use of the English language. As a fellow author, I am sure he appreciates your good usage.

I was at the retirement dinner for Dr. Abe Silverstein, formerly the head of Lewis Center, Saturday evening. I have been one of his admirers, so I would like the record to show we feel that under his leadership the Center has certainly done well, and fulfilled the research and development requirements of this country in very difficult years.

My question is on the integration of NASA centers with the centers of technology that are out in commerce, private industry, as well as in universities and colleges. With the chairman's permission, would you put a statement in the record on this, so that we can see how you relate to the general area of reference of research and development in this country?

Mr. LUNDIN. Yes, sir. In industry, universities and colleges?
Mr. FULTON. Yes.
Mr. LUNDIN. I would be very pleased to.
(Information requested is as follows:)

Aeronautical research and development in the United States has always involved a close relationship between government and industry and both have relied on universities for the training of men and women in the aeronautical sciences and for fundamental-type research. Government involvement in aeronautical research started over a half century ago and a primary reason was that large wind tunnels and related facilities were too expensive for an individual company or university to support. The use of these government facilities for many years has brought government, industry and university research teams close together. Military requirements for continuing improvements in aviation capabilities also drew industry and government into integrated efforts. In recent years, industry has built many new and large facilities but these are used primarily for development testing, and industry sees the need for the government to have facilities for advanced aeronautical research.

At the present time integration of effort between government agencies and between the government and the private sector takes many forms. Within the government there are coordinating organizations such as the Aeronautics and Astronautics Coordinating Board and its various panels and subpanels. An example of government, industry and university coordination is represented by the NASA Research and Technology Advisory Council and its Committees and Subcommittees which for aeronautics and space involves about two hundred members from universities and industry, about fifty from other government agencies, and over a hundred from NASA.

The NASA aeronautical research program itself provides a variety of integrating and coordinating efforts, e.g., joint programs with DOD and DOT and participation by universities and industry in NASA research work under contract.

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Mr. Philip Goodwin, Naval Air Systems Command, AIR 5203, Room 2W98, Navy Department, Washington, D.C. 20360.

Professor Ray W. Guard, Head, Department of Metallurgical Engineering, Michigan Technical University, Houghton, Michigan 49931.
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Mr. Louis P. Jahnke, Manager, Materials Development Laboratory–M82, General Electric Company, Cincinnati, Ohio 45213.
Mr. Harold D. Kessler, Corporate Technical Director, Reactive Metals, Inc., 100 Warren Avenue, Niles, Ohio 44446.
Mr. John V. Long, Director of Research, Solar Corporation, 2200 Pacific Highway, San Diego, California 92112.
Mr. Ira Petker, Technical Specialist, Composite Structures Department, Aerojet General Corporation, Azusa, California 91702.
Professor Robert A. Rapp, Ohio State University, Department of Metallurgical Engineering, 116 West 19th Avenue, Columbus, Ohio 43210.
Mr. Hyman Rosenthal, Research Advisor, Metallurgy Research Laboratory, Frankford Arsenal, Philadelphia, Pennsylvania 19137.
Mr. G. Mervin Ault, NASA Lewis Research Center, Mail Stop 105–1, 21000 Brookpark Road, Cleveland, Ohio 44135.
Mr. Michael Comberiate, NASA Headquarters (Code RAP), Washington, D.C. 20546.
Mr. James J. Gangler, NASA Headquarters (Code RRM), Washington, D.C. 20546.
Mr. Richard A. Pride, NASA Langley Research Center, Mail Stop 188A, Langley Station, Hampton, Virginia 23365.
Mr. Richard H. Raring, Executive Secretary, NASA Headquarters (Code RRM), Washington, D.C. 20546.

RESEARCH AND TECHNOLOGY ADVISORY SUBCOMMITTEE ON FLUID MECHANICS, FISCAL YEAR 1970

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Dr. Robert Arnoldi, Pratt & Whitney Aircraft, East Hartford, Connecticut 06027
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Dr. Robert Korkegi, ARL (ARR) Building 450, Wright-Patterson AFB, Ohio 45433.
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Dr. Frank Marble, Department of Aerospace Engineering, California Institute of Technology, Pasadena, California 91109.
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Dr. Harold Mirels, Aerospace Corporation, P.O. Box 95085, El Segundo, California 90245.
Dr. Mark Morkovin, Department of Mechanical and Aerospace Engineering, Illinois Institute of Technology, Chicago, Illinois 60616.
Dr. Henry Nagamatsu, General Electric Company, Schenectady, New York 12301.
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Dr. Simon Slutsky, Professor, Aeronautics and Astronautics, New York University, University Heights, New York, New York 10453.
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Dr. Dean Chapman, Chief of Thermo-Gas Dynamics Division, Ames Research Center, Moffett Field, California 94035.
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Dr. Robert W. Graham, Chemical Lab., Lewis Research Center, 21000 Brookpark Road, Cleveland, Ohio 44135.

Mr. Ira R. Schwartz, Executive Secretary, NASA Headquarters (Code RRF), Washington, D.C. 20546.

RESEARCH AND TECHNOLOGY ADVISORY SUBCOMMITTEE ON ELECTROPHYSICS, FISCAL YEAR 1970

Dr. Richard W. Damon, Chairman, Department Head, Quantum Electronics, Sperry-Rand Research Center, Sudbury, Massachusetts 01776.

Dr. Earl Callen, Department of Physics, American University, Washington, D.C. 20016.

Dr. K. M. Crowe, Professor of Physics, University of California, Berkeley, California 94720.

Dr. J. E. Drummond, Head, Plasma Physics Laboratory, The Boeing Company, Seattle, Washington 98128.

Dr. Wade L. Fite, Professor of Physics, University of Pittsburgh, 4200 Fifth Avenue, Pittsburgh, Pennsylvania 15213.

Dr. Robert G. Jahn, Professor of Aerospace Sciences, Princeton University, Guggenheim Laboratories, James Forrestal Campus, Princeton, New Jersey 08540.

Dr. Karl C. Kessler, Head, Atomics Physics Division, 164-2001 A & M Physics Division, Room B 164, Physics Bldg 221, National Bureau of Standards, Washington, D.C. 20234.

Dr. Alexander Lempicki, Head, Quantum Physics Group, General Telephone/Electronics Laboratory, 208-20 Willets Point Boulevard, Bayside, New York 11360.

Dr. James E. Mercereau, California Institute of Technology, Sloan Laboratory of Mathematics and Physics, Room 61, Pasadena, California 91109.

Dr. Norman Rostoker, Chairman, Department of Applied Physics, Clark Hall, Cornell University, Ithaca, New York 14850.

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Dr. Karlheinz Thom, Executive Secretary, NASA Headquarters (Code RRE), Washington, D.C. 20546.

Mr. FULTON. That is all, Mr. Chairman. Thank you.

Mr. HECHLER. Mr. Lukens.

Mr. LUKENS. Thank you, Mr. Chairman.

Mr. Lundin, I would like to ask two quick questions. No. 1, of the 5,000 employees you referred to, how many of those are actually engaged in laboratory work?

Mr. LUNDIN. I will give you two sets of numbers. If that doesn't answer your question, I will try again.

Of the 5,000, about 3,500, roughly, are what we call direct people. The other 1,500 are generally classified as indirect people, whose work is, say, in procurement offices, administrative and management, plant operations, who are not directly charged to an aeronautical program.

The ratio of, say, professional to technician or support generally runs—well, at the Lewis Research Center, of 4,200 total staff, about 1,700 are research professionals. It is about a 1-to-2 ratio.

Mr. LUKENS. Thank you.

And one last question which I wanted to ask. It will probably be a quick question, but not such a quick answer.

Since there is such a great need for close coordination with what you do, how we are trying now to devise total systems to replace other

systems, rather than just an engine component or air frame component? How does your Lewis Research Center coordinate the overall planning of this with other developments in the industry at various other areas? Through what boards? What agencies? How closely can we really coordinate all this going on at one time in America?

We are talking now about technology utilization. How closely can we coordinate development of new plants and new items?

Mr. LUNDIN. There are two levels or areas of coordination. One is coordination which occurs at fairly high levels here in Washington, such as the AACB, or our advisory committee system, which includes other agencies, industry, universities, and so forth. And that, I don't think, is too difficult a matter.

And then you will also find a very high degree of coordination of work of one group with another, in an area such as materials or electronics, at the working level, where there is essentially a fraternity of people who are exchanging their points of view and their ideas and concepts at meetings, in correspondence and in visits, almost continuously.

Mr. LUKENS. Pardon me, sir.

Mr. LUNDIN. Yes.

Mr. LUKENS. May I interrupt you?

Mr. LUNDIN. Yes, sir.

Mr. LUKENS. Is that an informal structure, then? The so-called fraternity?

Mr. LUNDIN. Yes.

Mr. LUKENS. Just so closely knit by mutual interests——

Mr. LUNDIN. Yes; mutual interests.

Mr. LUKENS. That it occurs by nature.

Mr. LUNDIN. Material specialists, say, have their counterparts on a friendly personal basis at other locations, and they keep amazingly good track of what the other fellow is doing.

Mr. LUKENS. Are there any areas of research you found had been overlooked in the past that are now drawn into this commonality of interest, in this fraternity? I mean, has there been any work done anywhere at any level, in any area of American technical society, that now we have discovered can be drawn in further, such as independent work on the campus that was not known before?

What assurance do we have that we are not overlooking or overlapping somewhere in the field of research? This is what I am really getting at. We have no virtual assurance of that.

Mr. LUNDIN. No; we do not. We are looking all the time. I cannot promise you that I am not overlooking something

Mr. LUKENS. Thank you.

Thank you, Mr. Chairman.

Mr. HECHLER. Thank you, Mr. Lukens.

Mr. Goldwater.

Mr. GOLDWATER. Thank you, Mr. Chairman.

Mr. Lundin, in the testimony that we hear, there always seems to be a tremendous emphasis on commercial aviation. I am just wondering whether you feel that the research done on commercial aviation, even on space, is benefiting in general aviation the airplanes which are in the majority in this country?

If so, how is this information or research being disseminated do..n to the general aviation people, so that they understand it, not being as technical or as knowledgeable in the technical field?

Mr. LUNDIN. Yes. I think your observation is valid, Mr. Goldwater, that most of NASA research is devoted to problems of military and civil aviation, such as noise, safety, and economy, and that the technical problems of general aviation, the small private owners, or the small airline probably are deserving of increased attention.

That it has not received a major focus in our research programs that the other areas have is perhaps because it lacks a unified industry, an agency of the Government or that sort of focus.

Their problems in the past have not been highly technical, either. They have been more oriented toward costs and economy of operation. But it is a field that I think should be deserving of increased attention, particularly as these smaller airplanes enter more and more the crowded traffic patterns, and fly at higher speeds.

Mr. GOLDWATER. Especially in the area of safety.

Mr. LUNDIN. Yes. We are, as you know, doing some work in connection with safety, including investigating spin characteristics of light aircraft and the application of yaw dampers to control dutch roll characteristics. You mentioned the proximity warning devices. So where we can find something that will contribute to the safety of such aircraft, and we have the capability to work on it, we think that is a useful thing to do.

Mr. GOLDWATER. How close are you to developing the proximity locater?

Mr. LUNDIN. I will have to provide that for the record. We are planning flight tests, but I cannot give you a date on when they are planned.

Mr. GOLDWATER. I would be interested in seeing that.

Mr. LUNDIN. Yes.

Mr. GOLDWATER. There was so much talk about it, but no one seems to come up with any concrete answers.

Mr. LUNDIN. There is a date planned for when it will be flight tested, but I am not——

Mr. HECHLER. Electronics Research Development, isn't it?

Mr. LUNDIN. Yes.

Mr. HECHLER. And we are having the head of Electronics Research Center down to testify.

Mr. GOLDWATER. Yes.

Mr. LUNDIN. He will surely know.

Mr. GOLDWATER. Thank you very much.

Mr. HECHLER. Well, this line of questioning that Mr. Goldwater pursued on the need for additional research in general aviation, I think, underlines what I was driving at, of the need for an overall top level policy that can fill these gaps.

But it is something, I think, that can and certainly needs to be done. I noticed several comments here that I would like to get clarified in your statement. Page 13, at the bottom of the paragraph at the top of the page, you say, "We will be paced here for some time to come by the capabilities of our experimental facilities."

Then a sentence on page 14, in the middle, you say, "Just what these future research facilities should be is, for the most part, for others to determine."

Finally, at the bottom of page 14, and at the top of page 15, "We should, I believe, concentrate a little more on doing and a little less on studies."

Naturally, we in Congress are interested in action as well as studies, but we feel the absence of serious planning for future requirements that is going on in NASA, and we would not want, by the emphasis on action, for you to downgrade the amount of planning for future requirements that we think is absolutely necessary if we are going to go in the right direction.

Now, all these things, of course, tie in with what I was saying before, about the necessity for some type of leadership statement that can enunciate national goals and priorities, and help tie all this together, plus the need for the planning for future requirements which must be done inside of an organization like NASA, if we are going to go in the right direction.

We can't let this entirely be dictated by what somebody says on the outside, or who screams the loudest at a particular time. Would you care to comment on any of this?

Mr. LUNDIN. Yes, sir. I'm sorry that my words may have carried the implication that I think we should do less planning. Perhaps I should have said we should concentrate more on doing, putting emphasis on experimental hardware from which to learn solid technical things, and less on design or systems studies.

I think we need to give more attention to planning and to experimental hardware, and it was a matter of emphasis. Doing paper design a system studies is no substitute for learning by running experimental hardware, is the point I wished to make.

Mr. HECHLER. This committee, as you know, has been very generous in the field of aeronautics, and in support of aeronautics. In fact, we have pushed a lot harder than NASA and the Bureau of the Budget have in terms of authorizing funds.

You mentioned the need for facilities. I find it difficult to figure out just what this committee has failed to do in terms of support of facilities, or what really needs to be done. What specific facilities are you referring to now that we ought to be supporting?

Mr. LUNDIN. I appreciate and applaud the support and understanding of this committee for all of our aeronautical activities. I have no specific facilities in mind at this time. I was taking a longer range view, and calling attention to the fact that it is my feeling that we need to do more aeronautical research facility building in this country in the decade ahead than we have done in the past decade.

I then wished to identify for the committee what I think some of the characteristics or the areas of future need that these facilities should be directed at, such as avionics, total systems work, transonic speed problems, and man-machine relationships. It is not possible for me at this time to propose specific facilities.

Mr. HECHLER. I recall at some point in your prepared statement you discussed the transferability of space technology to aeronautics. Where was that?

Mr. LUNDIN. In my testimony?

Mr. HECHLER. Yes. You made some mention of the applicability of what we had accomplished and learned in space to the development of aeronautics. I am unable to put my finger on it immediately, but I seem to recall that. Oh, yes, here it is.

Mr. LUNDIN. Page 13.

Mr. HECHLER. Page 13, yes.

Mr. LUNDIN. Benefits from the space program, yes.

Mr. HECHLER. Are there any other ways in which we could utilize the tremendous progress that we have made in space to further aeronautical research? Are there any blocks to the application of these things? Is there any other means that we can employ to derive the greatest benefits that we have achieved in space, and apply them to our aeronautical research advances?

Mr. LUNDIN. I have asked myself that question a number of times, and I have really no improvements to suggest, Mr. Hechler. We are presently organized within OART along discipline lines such that the same groups and almost the same people are doing space technology as are doing aeronautical technology, and our centers tend to be organized along such discipline lines as electronics or propulsion or structures materials.

There is no sharp division at the technical working level between space and aeronautical technology, so I can hardly find any barriers here that need to be tended to. Transference is best achieved at the working level and these discipline groups are well integrated.

Mr. HECHLER. Administratively, then, you think the arrangement is satisfactory?

Mr. LUNDIN. Administratively and organizationally, I cannot think of any way to further strengthen it.

Mr. HECHLER. One final question. Technically, is there any way in which any of the advances that we have made in space could be utilized in a more advantageous way to the advancement of aeronautical progress?

Mr. LUNDIN. They are being made. As has been mentioned on previous occasions, when we had Gemini guidance equipment in a helicopter to study automatic landing of VTOL aircraft, as one example.

I have no ready suggestions for increasing this flow of space technology to aeronautical technology.

Mr. HECHLER. Are there any other questions by members of the committee? If not, we want to thank you for appearing before the committee. It has been extremely helpful, Mr. Lundin.

Mr. LUNDIN. Thank you.

Mr. HECHLER. We will next hear from Dr. Raymond L. Bisplinghoff and Dr. H. Guyford Stever.

Good Morning, Dr. Bisplinghoff. Do you want to go first?

Dr. BISPLINGHOFF. Thank you.

Mr. HECHLER. Welcome back to the committee.

Dr. BISPLINGHOFF. Thank you very much.

Mr. HECHLER. We are very pleased that you and Dr. Stever could be with us this morning.

Dr. BISPLINGHOFF. Well, we are honored to be asked.

Mr. HECHLER. You may proceed.

STATEMENT OF DR. RAYMOND L. BISPLINGHOFF, CHAIRMAN, AERONAUTICAL AND SPACE ENGINEERING BOARD NATIONAL ACADEMY OF ENGINEERING

Dr. BISPLINGHOFF. We sincerely appreciate this opportunity to come here today, both Dr. Stever and myself, to express our views on aero-

nautical research and development. And I am particularly happy to be here today, because I was unable to accept your previous invitation to appear when hearings were held on this same subject a little over a year ago.

However, at that session you will recall that Dr. Stever did appear and discussed with you the civil aviation report of the Aeronautics and Space Engineering Board which had just been completed at that time.

Today we thought it might be useful to take a brief look at what has been accomplished in the year that has passed since our report was published, and highlight the issues that, in our opinion, are still in need of attention.

To set the stage for our assessment, I would first like to summarize and discuss some of the major conclusions and recommendations of the Aeronautics and Space Engineering Board report. Dr. Stever will follow with a review of some of the actions taken during the past year, and comment on the progress, or lack of it, in solving some of the critical problems facing civil aviation.

In addition, each of us will comment briefly on the problems and progress in the training of younger people, including engineers, for their entry into the aviation field.

To begin with, then, I would like to go back to a time about two and a half years ago, when Dr. Stever and I began thinking seriously about how to strengthen the Nation's aeronautical research and development capability and how to apply that capability more effectively to the problems of civil aviation. We talked about this problem with officials of the NASA, Department of Transportation, Federal Aviation Administration, the President's Science Adviser, some Members of Congress, and the National Aeronautics and Space Council.

These discussions confirmed our belief that a study of the Government's role in aeronautical research and development for civil aviation would be a worthwhile undertaking for the Aeronautics and Space Engineering Board.

I won't go into the details of how we conducted the study, since that was described and recorded in the subcommittee report of the 1968 hearings on aeronautical research and development. I will simply mention that we organized our study effort in six areas—flight vehicles and propulsion, aircraft operations, air traffic control, airport and support facilities, and aircraft noise.

We invited several engineering societies to assist in the study and received valuable assistance from the American Institute of Aeronautics and Astronautics, the American Society of Civil Engineers, the American Society of Mechanical Engineers and the Society of Automotive Engineers.

I might mention, Mr. Chairman, that this is the first time that one of the academies have used the professional societies in such a complete way.

The study took about a year, and was concluded with publication of a summary report in August 1968. This study and its follow-on activities form the basis for many of the remarks which will be made today by both Dr. Stever and myself.

Not much more than a quarter of a century ago, civil air transportation was the domain of the enthusiast. Air transportation depended

at first upon the enthusiasm and devotion of its followers. It was watched at the same time with indifference by the nonair traveler. If the birth of air transportation had depended upon cost effectiveness, or even elementary economics, I think I am safe in saying that it would have taken much longer to develop, if indeed it would have started at all.

There was a similar early pattern in the early development of flight vehicles. They were developed at first almost entirely by ad hoc experimentation. There was a certain disdain on the part of the recognized scientist toward early practical aviation, not unlike that found a few years ago at the beginning of the space program.

Yet, enthusiasts alone could not have brought the airplane along so fast and so far. The crucial factor was the stimulus provided by warfare. Commercial air transport technology was fanned into brightness by the wings of combat military aircraft. This was once a blessing, but now it produces a problem because the gap between military and civil aviation is growing. The military is relying more and more on missiles and highly specialized flight vehicles.

At the same time, the peculiar conditions under which civil aviation now operates have created air vehicles which are economic only under these special conditions. In fact, the technologies required to achieve economies in commercial flight vehicles will increasingly exceed in sophistication those needed by the military. The kinds of technologies, for example, that are required to make the supersonic transport economically attractive are in many ways more difficult to achieve than the principal technological goal required by the military; namely, performance.

It is becoming increasingly clear to me that future flight vehicles for civil air transportation will be influenced less and less by developments in military aeronautical technology, and more and more by the total air transportation system in which they will operate.

In the past, most of our aeronautical research and development organizations have been concerned primarily with improving the flight vehicle. But the flight vehicle is only one segment of the total air transportation system, and these kinds of research and development organizations must now seek goals that improve productivity of the total system, not only the flight vehicle part of that system.

This says that civil aviation research and development should be directed toward the most critical problems of the total system, and these problems may not necessarily be those of improving the lift to drag ratio of air foils, the strength to weight ratio of materials, and the thrust to weight ratio of engines.

The growth rate of civil aviation is going to be the result of a balance between those forces that tend to drive it to high levels—such as increasing public demand for transportation, and a favorable economic climate—and those forces which will tend to impede its growth.

A question frequently asked is whether the historic upward trend in the growth of civil aviation can be expected to continue through another decade or, indeed, through another half decade in the face of the various restrictions which we see coming into play.

I personally believe that in a favorable climate, this upward trend can be maintained and even accelerated if a program of planning and research and development aimed specifically at the civil air trans-

portation system is followed. This cannot be simply fallout from the research and development program of the military, but a program which is aimed specifically at the civil air transportation system itself.

The pressures that are tending to increase the growth of civil aviation are real and will continue. I think the most important thing that faces us now is to identify and solve the problems which might otherwise limit its potential. The three most pressing problems today are airport facilities, noise, and air traffic control. You may recall that these are the same as those highlighted in our Board report and discussed by Dr. Stever before the committee last year.

Any of these can exert strong inhibiting influences on the growth of air transportation unless satisfactory solutions can be found. These three areas, as you recognize, are closely coupled in that they all relate to the ability of our air transportation system to accept and dispatch aircraft at key terminal points with safety and efficiency, as well as with acceptance by the surrounding community.

There are at least two major obstacles to development of an adequate national airport system—financing and planning. Before one can do anything about this matter, it is essential to have plans at both the national and regional levels that will assess capabilities, estimate the demands, and identify steps necessary to meet requirements.

Although very little has been spent in the past on research and development directed toward airports—in comparison to the research and development funds invested in flight vehicles—I believe that substantial returns can accrue from funds spent in this area.

I know there has been increasing interest in airport planning both within the Government and in nongovernment organizations, and Dr. Stever will touch on some of these activities in his statement.

However, I am convinced that much more needs to be done in long-range airport planning and development at both the national and local levels, if we are to have the airport facilities required for the advanced commercial transports that will be flying in the future.

The growth of civil aviation has brought a world-wide concern for the noise produced by large aircraft. If one goes back and looks at the record, one sees an increasing noise level with the successive introduction of advanced aircraft. And it is very likely that the introduction of the new generations of transport aircraft will produce even higher noise levels in neighborhoods under flight paths or to the sides of runways. The very large engines, for example, in the SST will produce sideline noise levels much higher than any existing engines or aircraft.

It is clear that the aircraft noise solution must include the development of quieter aircraft. This will not be easy, because we are up against the laws of physics which tell us that as we increase the power of engines and the velocity of the jet efflux from the back of the engines, we are naturally going to generate more noise.

In addition to noise reduction at the source, we are going to have to apply Federal noise criteria and noise standards for aircraft, develop consistent land use practices in areas surrounding airports, and develop low- and modera[illegible]-cost building, air conditioning, and soundproofing techniques to reduce noise inside houses already in such areas.

Although substantial empirical knowledge and some scientific theories exist concerning the sources of aircraft noise and the technology for its partial control, I am sorry to say that the scientific basis for

understanding the primary noise generating mechanism is inadequate.

Research in this country generally has not been aimed at the fundamental physical problems of jet noise generation and propagation, but instead has been conducted primarily at the engineering level, and consists largely of ad hoc attempts to reduce noise.

There is almost a total absence of basic research in physical acoustics that would further our understanding of jet noise. Current research on human reaction to aircraft noise should also be continued and extended.

With increased air traffic and introduction of new kinds of aircraft noise, it is of the greatest importance to have more accurate information about human response to different characteristics of noise and to a total environment in which noise may be an important element. And there is a shortage of qualified research scientists to undertake such research programs.

Of course, right now, the several arms of our Federal Government are becoming very much interested in investing money in research and development on jet noise abatement and the propagation of jet noise through the atmosphere. But, if we follow customs of the past, as soon as the immediate crisis is over the money will be withdrawn and no serious long-term program will exist.

I hope that we will not follow the past, because noise is becoming increasingly important in all walks of life, and we should understand as thoroughly as we can the basic mechanisms for its generation and propagation.

You may think it strange that I mention air traffic control after noise and airports, in view of the recent difficulties we have had. I do think, however, that in terms of long-term complexities of the problem, the other two problems are more difficult to solve.

The noise problem, for example, involves bucking laws of physics which are going to yield very slowly and at great cost. The airport problem, of course, involves more than technical matters; it involves social and economic and metropolitan and national planning problems which I believe are extremely difficult, perhaps the most difficult of all.

As far as air traffic control is concerned, I think many of us can see long-term technical solutions providing we get to work on the problem. Of course, the air traffic growth recorded in the past 4 years, coupled with the forecast for future growth, indicates that air traffic will be increasing at a greater rate than the present or programed air traffic control system can handle.

All of this is clearly going to require new approaches to air traffic control in the future. The forecast indicates that deficiencies now evident in the Nation's air traffic control system will become progressively worse unless strong measures are taken to correct an imbalance in volume of traffic and capability.

I believe there are areas where more vigorous effort to apply existing technologies can pay large dividends in evolving an adequate air traffic control system. At the same time, there are areas where renewed emphasis on research and development is clearly needed.

In discussing each of the three major problems of civil aviation, I touched on some general areas in which more research and development are needed to improve the situation. The Aeronautics and

Space Engineering Board also made other recommendations concerning governmental responsibilities in civil aviation research and development. The first has to do with the organization of the Federal Government insofar as civil aviation research and development is concerned.

The Board believes that strong Government participation and leadership will be required if civil aviation is to continue to grow as it has in the past. This participation and leadership must come from both the legislative and executive branches of the Government, through wise policies and their effective implementation.

I would say that aeronautical research and development now in the United States is analogous to a university fielding a group of intramural teams, instead of a varsity team. The reason for this is the lack of both effective leadership in the Federal Government and resources.

And let us say, akin to the leadership we found in the case of the space program.

There are vast R. & D. resources in the universities and in industry in the United States not now employed, and only the Federal Government can act as coach of this team and mold it into a varsity team.

I think if it is Government policy, that this be done; in my opinion, it is not now being done. If it is not Government policy to do this, then we are doing pretty well.

I would remind you again that flight vehicle development in this country has been based almost entirely on military technology. For example, the technology that is used in our air traffic control system today has been derived almost entirely from military developments during and just after World War II.

The military developments and interests are diverging from the interests and desires of the civil air transportation system. Therefore, new technologies and new developments are going to have to come increasingly from independent action directed toward the civil air transportation system itself.

With the creation of the Department of Transportation, the Federal agencies and their charters are now structured such that the Government should be able to exert its proper leadership role in civil aviation research and development.

The Board believes that leadership should be provided by the Department of Transportation in carrying out systems studies to identify, analyze, and rank goals for our civil aviation system. And these goals should be formulated with reference to the Nation's total transportation system, taking account of the increasing public demand for air transportation, as well as the various economic factors.

Although inhouse Government capabilities should be developed and maintained by DOT for this purpose, it is believed that industry and other private institutions could participate in carrying them out.

But then there remains the problem of research and development itself. And the long record of outstanding performance by NASA and its predecessor, NACA, in research and development clearly suggests that this Agency should play even a greater role in aviation in the future.

NASA's role should be expanded to involve not only flight vehicles and their propulsion systems which have traditionally occupied NACA

and NASA in the past, but all aspects of research and development of importance to civil aeronautics.

It is going to be important for NASA to adopt a policy of directing its attention to those research and development goals including the development of carefully selected experimental hardware that optimize the productivity of the total civil air transportation system.

Such expanded activities, for example, could involve the development of new technologies relating to air traffic control, as well as to airports and support facilities. With regard to air traffic control, this does not imply that the responsibilities and authorities of the DOT and FAA should be diminished.

NASA's background in vehicle technology, together with a growing capability in the field of avionics, enables it to assess important tradeoffs that must be made between onboard and external avionics systems, and to play an important supporting role for the FAA and DOT. Also, recent developments in space technology, including the use of satellites for communications and navigation, offer very important new opportunities for improving air navigation.

I would like to comment briefly on the important question of proof of concept as a Federal Government responsibility in the field of aviation. The Board defined proof of concept as a phase in development in which experimental hardware is constructed and tested to explore and demonstrate the feasibility of a new concept.

It is clear that this has been and will continue to be an important and necessary step in the development of new concepts suggested by successful research. It can be an equally important step in defining areas requiring further research.

It is our view that if NASA is to conduct "proof-of-concept" programs in areas of new technology, it should do so only when the potential capability of a new development is apparent but (*a*) not economically attractive to the private sector; (*b*) the cost of the "proof-of-concept" is beyond the means of private capital; (*c*) several related ideas competing for Government support can only be evaluated objectively by test.

Proof-of-concept programs could serve to reestablish vital cooperative relationships between NASA and the Armed Forces, other Government agencies such as DOT and FAA, and, in some cases, private industry. This, of course, is useful, but is not by itself sufficient reason for the existence of such programs.

Proof-of-concept is an expensive step in the R. & D. cycle and, as such, should be considered only for developments of significant importance to the Government or local communities. Proof-of-concept must be conducted carefully, and the necessity of its insertion into the R. & D. cycle must be based on solid technical judgment.

Such programs must represent sufficient advancement in technology to uncover other areas of needed research, but it must not be so revolutionary that proof, or lack of it, cannot be achieved within reasonable time and cost.

Finally, "proof-of-concept" must not be used to develop prototypes of potential production vehicles or systems for which there is no agreed-upon requirement. The Board believes that with these qualifications, NASA should be encouraged and supported in the conduct of proof-of-concept programs.

Although continued research and development on the technologies of the air vehicle are absolutely necessary, I have placed such work, insofar as it relates to the growth of the total air transportation system, behind airports, noise, and air traffic control.

The air vehicle, of course, is just one element in the total transportation system. It has, so far, received the lion's share of attention, and it continues to outstrip the rest of the system in performance. What does the future air vehicle technology picture look like?

Projected improvements in subsonic conventional takeoff and landing vehicles appear more than adequate to meet the challenge of rapid increases in air travel over the next two decades. But the potential economic advantages of these design improvements will surely be lost if air vehicle technology does no more than compensate for the lag in operating and supporting environments.

In the next decade, medium- and long-haul subsonic aircraft will undergo great improvements in the area of avionics, including guidance. Refinements in propulsion, structures, and aerodynamics will be continually introduced in subsonic aircraft.

Particularly, however, in avionics do I see considerable improvements. Avionics, until now principally exploited in military aircraft, is just beginning to make a corresponding impact in commercial aircraft.

Extensive application of this can be foreseen in navigation, automated check out, airborne computation, instrumentation, aircraft control and communications. Better integration with the ATC environment should allow more operations in bad weather and greater safety in a much more crowded airspace.

The growth of conventional takeoff and landing subsonic aircraft in passenger and cargo capacity will continue. There is no fundamental technological reason whatsoever why takeoff gross weights cannot approach a million and a half pounds.

Today's subsonic conventional takeoff and landing jet transports are the result of a natural selection that has standardized the most desirable features—the swept-back wing, and the mounting of engine pods on the swept-back wing—and has set a pattern which has been followed with great success.

But such a growth process has not yet occurred for V/STOL aircraft. There are a multitude of designs, each of which has received only a small amount of technical concentration. This makes it difficult to pinpoint trends for these aircraft as sharply as can be done for conventional takeoff and landing subsonic aircraft.

In my view, short takeoff and landing technologies are sufficiently well in hand to permit us to do a great deal more than we have already done. We can build STOL aircraft with satisfactory cruise performance which can operate on auxiliary strips out of the normal jet pattern. I foresee extensive application of STOL technology in the next few years.

VTOL technology, however, is another matter. Aside from the helicopter and a variety of experimental applications, there is little to go on. Helicopter economics are not attractive and, for fundamental reasons, are unlikely to improve. In the VTOL area, studies are required to narrow down the numerous vehicle concepts to the most promising, so that they can be given the benefit of focused development.

Demonstration projects should be conducted and designed to obtain reliable economic and operational data required by investors, manu-

facturers and operators, before this type of aircraft is committed to a full scale short-haul system.

Looking at long-range transportation beyond conventional takeoff and landing subsonic aircraft, a few words ought to be said about supersonic and hypersonic flight. The distances between the major world cities are of such magnitude that speeds well into the supersonic and hypersonic range can offer attractive advantages to travelers.

If one takes account of traveltime to and from airports, with subsonic jet transport, the total trip time is about a working day when distances exceed 3,000 nautical miles. When the first generation SST comes into being, a journey of 3,000 nautical miles will require about a half working day.

And if we accept a half working day as a desirable trip time, a hypersonic transport can provide transportation over many thousands of miles without increasing travel time. A sizable step beyond the supersonic transport would be the capability to transport passengers hypersonically over perhaps 6,000 nautical miles, or from San Francisco to Tokyo, cruising at mach numbers 5 to 6.

The next stride might be 10,000 nautical miles, joining San Francisco to Melbourne, or New York to Cape Town, at mach numbers 10 to 12.

Mr. HECHLER. You will be in orbit pretty soon.

Dr. BISPLINGHOFF. All of this is not idle imagination. When the aeronautical engineer looks at the Breguet range equation, he finds that by cruising at these high mach numbers, using hydrogen fuel at altitudes of 120,000 to 150,000 feet, one can achieve flight efficiencies greater than any we have ever achieved.

Although it may be the turn of the century or later before such aircraft are finally developed, I have no doubt that they will be. Unfortunately, hypersonic vehicle technology is receiving almost no research and development attention at the present time.

I would like to close this statement with a few brief remarks on the problems and progress in the training of younger people, including engineers, for their entry into the aviation field.

It is my observation that there has been a decline over the past decade in younger people entering the profession of aeronautical engineering. There are several reasons for this decline. Perhaps the principal reason has been the attraction and opportunities of space research and development for these young engineers who graduate from Departments of Aerospace Engineering in our universities.

The rapidly expanding activities of the military missile programs and the civilian space program absorbed many young people who might otherwise have practiced aeronautical engineering. Another reason is the unavailability to universities of research and development funds for atmospheric flight vehicles.

It is now a fact of life that most graduate students of science and engineering are supported by research grants and contracts obtained from the Federal Government. The subject matter of their graduate research is often dictated by the moneys made available by Federal funding agencies.

Thus, the graduate research interests of the Nation's science and engineering students are to a considerable extent governed by programmatic and budgetary decisions made in Washington. These deci-

sions, which have made relatively little money available for research and development on atmospheric flight vehicles, have been reverberating through the educational world for a decade.

A third reason for reduced interest on the part of young engineers and scientists in atmospheric flight, in my view, is the steady decline in the number of new aircraft types, including prototypes, developed in the United States.

Prototype construction and experimental hardware developed and constructed to explore and demonstrate the feasibility of new aeronautical concepts are essential elements of our program for a variety of reasons if we wish to maintain aviation leadership throughout the world.

All of this adds up to an increasing average age of engineers engaged in the research, development, and engineering of atmospheric flight vehicles. The higher-than-average age of that component of the NASA staff engaged in aeronautical research and development is illustrative of this point. This trend will not, in my opinion, be altered significantly unless changes can be brought about in the three areas just mentioned.

Thank you very much.

Mr. HECHLER. This is an outstanding statement, Dr. Bisplinghoff, and it shows great depth and perception, drawn not only from your practical experience, but it shows, I think, a measured objectivity which we appreciate.

If it is agreeable to other members of the committee, I think it would be better to defer questions on your statement till after we hear from Dr. Stever.

We welcome you back again to the committee, Dr. Stever.

Dr. STEVER. Thank you.

Mr. HECHLER. We welcome you as a distinguished member of the Panel on Science and Technology, as the distinguished president of the Carnegie-Mellon University, and the Chairman of the Aeronautics and Space Engineering Board at the time the report was prepared.

I understand you have been demoted on the Board to a mere member, is that right?

Dr. STEVER. That's right; yes, sir, Chairman Hechler. Yes, I have been demoted, but this was by a long-term agreement with a very good friend, that I would do it the first 2 years if he would do it the second 2 years.

Mr. HECHLER. Good to have you here, Dr. Stever.

You may proceed.

STATEMENT OF DR. H. GUYFORD STEVER, MEMBER, PANEL ON SCIENCE AND TECHNOLOGY, HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS

Dr. STEVER. Chairman Hechler, members of the subcommittee, I appreciate the opportunity to discuss with you some of the issues and problems involved with civil aviation and some of the actions involving aeronautical research and development that have occurred during the past year.

You have just heard a general review and restatement of the views of the Aeronautics and Space Engineering Board of the National

Academy of Engineering, on civil aviation research and development and the Federal Government's involvement.

I have taken the task, to follow Dr. Bisplinghoff, of trying to tell you what we have observed happen in the year or so since our report was published. A far better understanding of current problems has been developed. There is a growing realization that these problems will worsen unless strong measures are taken. But not enough is being done now to meet these problems.

I do agree with Mr. Pelly that we can point to some new pieces of progress. He mentioned the improvement in the noise, in the introduction of the 747, and presumably other members of that generation of aircraft.

I think that really has come about by applying the knowledge that we have had in the noise field, when it became apparent that we had to apply it. But I still would agree with Dr. Bisplinghoff's statement that there is a great deal that we don't know about the fundamentals of noise, and as we are asked for future solutions, better solutions in the noise problem, finding them will be more difficult.

Still it is very nice to realize that when a problem is pinpointed and people get interested and even excited about it, and all of the mechanisms in Government and in the private sector including technical groups and industry begin to focus on the problem, progress can be made.

We believe we see a considerable improvement in the communication of ideas in this field, among the technical community and elements of the public and private sectors. As examples, in addition to the active interest your committee has taken, in the fall of 1968, and now here in the fall of 1969, the American Institute of Aeronautics and Astronautics shortly after publication of our ASEB report, devoted their "president's forum," a general session of their annual meeting, to consideration of the question, "How Should Civil Aviation Develop to Serve Our Society Best?"

It was my privilege to address the group with the results of our study and participate in the discussions. There was a very broad representation from industry, the academic community, and Government at the meeting, and I feel that as a result there has been considerably more activity toward solution of the many problems discussed.

At about the same time last year Dr. Bisplinghoff addressed the members of the Airport Operators Council International (AOCI) at their annual meeting. As he noted, there has been increased interest and activity on the planning necessary to improve airport and terminal facilities.

As a matter of fact, the AOCI and others, including the American Road Builders Association and the Aircraft Industries Association, to name only a few, are actively considering ways to improve the airport planning process on a national scale.

These and other efforts are all to the good. Further, I believe that along with these activities the news media are now devoting more time to the area of aeronautics, particularly to the problem areas and possible solutions. I think we can say that during this past year a good many more people both in and out of Government have begun to think and talk more about civil aviation, and hopefully this will result in greater effort and thus more rapid solution to the problems facing us.

Unfortunately, the communications are not always on the same wavelength, for many propose the suppression of civil aviation to get rid of nuisances such as noise, air pollution, ground traffic congestion around airports, et cetera, while others propose elimination of the nuisances so aviation can grow.

Our board has been concerned that, even though a number of excellent studies have been completed over the last few years and even though there has been fairly general agreement that some recommendations made should be implemented, the implementation just has not occurred at a satisfactory rate.

One might dismiss this lack of action with the observation that there just has not been enough money to do the necessary work. That answer is too easy. This country has, and I believe will continue to have, enough resources to do the things necessary to permit reasonable growth and efficient operations in all important fields.

It is true that more money will be needed, but along with that, as Dr. Bisplinghoff has noted, should come much more complete analysis, more comprehensive overall planning at the national as well as local level, and better organization of the Government elements working on the aviation problem.

I might elaborate just a moment on the need for analysis of the overall transportation system. It would seem that the concepts of systems analysis might be ideally suited to this job relating to the growth of our transportation system, analyses taking into account technical problems, economics, sociological factors, regulatory factors, noise, pollution, et cetera.

Such analyses can suggest ways to optimize the transportation network. We are encouraged that NASA and DOT have agreed that NASA's Mission Analysis Division should look at the methodology involved with such analyses. Hopefully, this may lead to better use of analysis techniques in the civil aviation field. If so, it will be a neat example of spin-off from space technology, since the Mission Analysis Division has been most occupied with space problems.

Our board has been concerned also to find out what specific actions, if any, have been taken by NASA and DOT as a result of the recommendations made in our report. During our discussions last summer with NASA officials, when I say "last summer," I mean the summer of this year—they indicated that the report had been used extensively in reshaping their aeronautical program.

Of the approximately 100 recommendations, 19 pertained to other agencies, but of the remaining 81, NASA had responded to all but 15. Where there had been no response, the reasons were primarily lack of funds and/or staff to take action. Finally, NASA noted that they had found the report useful during their budget formulation process.

We also see increasing evidence that NASA has instituted closer coordination with DOT and DOD in the aeronautics area. For example, in response to a DOT request, NASA is doing research on the vortex effect behind aircraft during landing, particularly for the case where parallel runways are being used.

And it is very clear from some of the things that Dr. Bisplinghoff said that the great traffic jams in the large city airports are going to require more parallel runways. Additional effort is planned on aircraft noise reduction with establishment of a new noise research laboratory at NASA's Langley Research Center.

That Center has increased its aeronautics staff by about 30 percent, and the Lewis and Ames Centers have likewise increased their effort on aeronautics. A special study group has been established by NASA to identify areas in which the NASA Electronics Research Center may assist DOT–FAA. This is one of the specific actions we feel may speed the transfer of technology acquired in space programs to the civil aviation field. As Dr. Bisplinghoff noted, we believe there is much to be gained, particularly in the traffic control field, from such an effort.

With respect to the future, it is encouraging to note that NASA and DOT are cooperating in their budget formulation process to produce a coordinate aeronautics program. A far better balance in their programs should result. As you know, DOT and NASA have begun a 15- to 18-month study of civil aviation research and development policy.

Associated with this effort, there is a study advisory committee on which Dr. Bisplinghoff and I, together with other members of the ASEB, as well as other members of the aeronautics community, serve. Our committee plans to meet with the DOT and NASA study chairmen, study director, and working groups every 2 or 3 months over the next year to review progress made in the study and the planning for subsequent work.

The advisory committee, made up of highly knowledgeable engineers, technical and financial managers, and operators from various fields of civil aviation, should provide expert and broad advice and counsel to the study managers.

Such detailed studies and analyses are needed, but I believe, and I am sure that Dr. Bisplinghoff agrees, that many of the remedial actions that must be taken to improve civil aviation are already known. When the remedies are known and when they can be agreed on, we would urge that funds be provided and work started. Later efforts can then be phased in as they are identified. In short, a great deal of valuable time has already been lost, and we strongly urge prompt implementation where there has been agreement on a plan of action.

From our discussions with NASA we are aware of some additional technical efforts on aeronautics they have underway. For example, in the electronics and control area there has already been an increase in effort on automatic landing systems, pilot warning or collision indicators, satellite servicing instrumentation, and computer technology.

In biotechnology and human research areas additional work has been initiated in the fields of noise, aircraft operations, and human factors aspects of air traffic control. There is increased effort in basic research on materials, aerodynamics, and detection of clear air turbulence.

Additional work has been undertaken in aeronautical vehicles research and development on hypercritical wings, engine noise, advanced flight simulators, various flight test programs, and structures. In one sense that paragraph is a small summary of some of the things that Mr. Bruce Lundin has been telling you, but in this case it is the observation of somebody from outside the Government as opposed to inside the Government.

I have already touched on a number of areas where DOT has begun additional activity with NASA. DOT has also undertaken other activities that give promise for the future. During the past year DOT and

NASA officials at the Assistant Secretary level and at lower levels have been meeting and working toward more effective cooperation. Also, as you know, the Secretary of Transportation in July 1968 established within the DOT a committee chaired by Mr. Ben Alexander—I believe he has testified before your committee—to study long-range air traffic control problems, to develop solutions, and to report on their findings.

While many of their recommendations have been transmitted to working groups within DOT and NASA, I understand that the formal report will soon be published, and that it will provide much of the specific information needed to point the way toward an adequate air traffic system for the future, again a subject which Dr. Bisplinghoff talked about.

The Secretary also asked the Electronics Industries Association (EIA) to establish a panel to study and recommend improvement of existing and plans for future air traffic systems. I understand that during its deliberations the EIA worked in cooperation with the Alexander committee.

And I would like to make another parenthetical remark, Mr. Chairman, about this. Dr. Bisplinghoff pointed out that the ASEB studies of a couple of years ago, are the first example in which the professional societies were brought heavily into the work of the national academy.

Here is another example of an outside association brought into the work when problems were being studied. My personal feeling is that in the study phase it is an extremely profitable thing to have members of Government of all branches, legislative, executive, and the trade associations, the knowledgeable engineering and science societies, the national academies, to work together.

The communication is so much better in arriving at studies that way then it is by having one group go into its own closed room to come out with its idea, and then exchange it with another group from its closed room. I really think this technique which is developing is a very important—I won't say tool for Government—tool for our society.

I might mention one other example of increased activity and interest in aeronautics. Our board members and staff have had discussions with Col. William Anders, Executive Secretary of the National Aeronautics and Space Council, and members of his staff, and are encouraged by the fact that he and his staff intend to devote a considerable amount of time to the aeronautics area in the future. We believe this is a very promising development, and we hope it will lead to increased recognition and support for aeronautical programs.

In summary, then, it is my feeling that the past year has brought awakened interest in civil aviation and some increase in activity. I feel, however, that there is an urgent need for the accelerated and expanded program of aeronautical research and development which we have recommended, the signs of which are now beginning to emerge. We would urge greater support for these civil aviation and aeronautics research and development programs than we believe is currently programed. Particularly, more implementation of ideas already agreed as important is needed.

All of this gives some indication that there is some improvement in the attitudes, organization, and support of research and development pointed toward civil aviation. But there remains some serious questions which your committee must address.

One pertains to the basic assignment of the responsibilities for the field of civil aviation research and development. One of the conclusions, I believe one of our most important, in the report by the ASEB recognized that the DOT, in particular FAA, was the focal point of civil aviation problems and Government operational responsibilities, while on the other hand, NASA has more competence in research and development as well as larger aeronautical research and development funding.

The recommendation that NASA be given more research and development responsibility grew from those thoughts. I think, however, that this committee must examine the record today and the near future to see if the cooperative efforts of DOT and NASA are producing the results. Otherwise other arrangements must be sought, arrangements that in fact bring the talent, facilities, and funding of these organizations into more effective combination.

Of particular concern to me is the magnitude of the relative space-oriented and aeronautical-oriented budgets within NASA. There will be changes over the years in NASA budgets because of the changes in space objectives. If these result in decreasing space budgets, the aeronautical research and development budget should not be simply attached to the space level but should be independently handled, and adjusted to fit the problem.

There are some other frequently cited points about civil aviation which should be reexamined. In fact, I would have a slightly different opinion today than I did a year ago with respect to this relationship between military aviation research and development and civil.

There is the often stated point that civil aviation used to be the direct beneficiary of military aviation research and development, but that now military and civil aviation are pursuing such divergent paths that there is no longer this close relationship.

I think that that is true, but if we are to permit our thoughts to carry that to the extreme, we will again be wasting a major effort in the country, because although the aircraft and related equipment budgets in the R.D.T. & E. budget of the Department of Defense have been going down, I have the results here, approximately $800 million, in the year 1965, going to $845, going to $744, $762, $539, and $645, over the succeeding years, to the 1970, although aircraft and related equipment budgets have been going down, that still is an immense amount of work in the aircraft field, and so we shouldn't carry this statement to its extreme.

Mr. HECHLER. Total R.D.T. & E. has gone up during this period?

Dr. STEVER. Yes, R.D.T. & E. budgets have gone up although they are about now to the same level as 1965, according to this statement. I would have to check that, to see its accuracy. But your statement is generally correct, the gap is wide, but still, that is an immense aircraft and related equipment budget and we shouldn't lose sight of the fact. We shouldn't carry this statement that civil aviation and military aviation are diverging to the end point in which we say we can't get anything out of it.

They are somewhat divergent but the elements of commonness are much greater than recognized, especially in components such as engines, controls, et cetera, as well as materials. Even in prototype development there are occasional elements of commonness.

By way of example, civil aviation awaits the development of intercity VTOL and STOL; the military services want light, medium, and heavy intratheater transports. I believe that avenues should be explored in which some of these prototypes common to both military and civil aviation are developed.

May I say only one other word. The chairman requested comment on the problems of education of engineers to handle the growing list of aeronautical problems. Dr. Bisplinghoff gave a recital of several points with which I agree. I would like to go a little farther, though.

My observation is that technical education, in general, is in serious straits for two reasons. One is that there is a very widespread mood for not venturing forward in technology at this time. There is also a clear-cut drop in real support by Government for advanced work in science and engineering. This is leaving an impact on engineering and science schools and their students.

This point has been magnified by Dr. Bisplinghoff. I would like to say to you that youth, especially youth in the technical fields, bears the brunt of recessions. At the present time, while the country is going into a mild tightening of its operations, that is in industry and so on, budgets are being tightened, there is a leveling off of research.

The youth get this in the magnified form because when any agency, whether it is Government or academic or industrial, is asked to tighten, it tends to keep the people already employed, and handle them, because of the feeling that it has a responsibility, and the hiring of new young people is greatly reduced, and so they bear most of the brunt of a cutback.

And I believe this effect has already started in the fields of science and engineering. If the Congress supports generally the need for better science and technology, one of the essentials for a strong and growing economy, thus aeronautical education will share in that strengthening. This is a belief that I have. I think that, as I say, that aeronautics is the beneficiary of a very broad science and engineering effort in this country, and when that broad effort suffers, so also does aeronautics.

Thank you very much.

Chairman Miller. Mr. Chairman, I must leave very soon. I want to congratulate both of these gentlemen. Of course we look upon Dr. Bisplinghoff as sort of a postgraduate of NASA, and recognize Dr. Stever for his long service on our panel.

I was very much interested in some of your last statements, Dr. Stever. We have a university grant bill that we had hoped to get out before this. We still will continue to press it, making some block grants to universities, because among other things, this committee is charged with certain work in the field of scientific education. I am very happy to hear you again, because you were one of the first that appeared before the committee.

I want to assure you that we are still trying to go forward. I am very much interested in the things that you say, and I want to congratulate Mr. Hechler on the work that he is doing. I am going to have a talk with him about doing some work in supervising and getting reports to us regularly on the cooperative work between DOT and NASA and other agencies of Government.

Unfortunately, some of the legislative authority is spread over a number of committees and it makes it very hard. I am very much concerned with what you have to say about airports, because as one

who travels a great deal between here and the Pacific Coast, I am conscious of the length I have to walk when I get off an airplane before I can get to my transportation.

I have tried to figure the times and the length of time it takes me to make a reservation, and get a ticket. Now, maybe I don't go down and get a ticket, but I have to send one of the girls down for a ticket and she may have to stand around for 25 or 30 minutes waiting her turn.

If I go down I get it a little quicker, but that is not fair. I have added all these things up, getting your baggage to and from airports, and I find that I can cross the continent in about 300 minutes from take-off to landing. If the wind is right we will cut sometimes 30 to 40 minutes off that.

But it takes over 200 minutes to do all of these related things before I can get on the airplane and get off it. I have even tried making a change from the west coast at Chicago to come into National because it is a little easier to get in town from National. But you do occasionally get some bad weather in the Midwest, and I have sat around many hours in the airport at Chicago, waiting to make my transfers.

So then you decide it is better to get to your destination and not transfer. But in this matter of airports, I don't know. I hope that your group gives some real serious thought to this problem. Is it going to be necessary for the Federal Government to establish standards? Or are we going to get a parochial feeling in many cities, that they have the better architect than somebody else, and he is going to lay out an airport as he sees it, and they can talk about their beautiful airports?

When I first went out to Dulles I thought it was for the birds. I think now it is the best airport in the world today. I say the world because I have been in quite a few of them and I haven't seen one that beats it. But, are we going to have to come to this: to establish a universal standard for airports?

The Federal Government helps build them. But we let the local people design them. For instance, in Los Angeles, if you come in on one airline, there is maybe 400 or 500 feet that you have to walk from the airport to the terminal. If you come in on another airline, they have a moving sidewalk that helps a little bit.

But the other airlines haven't seen fit to make this investment. I asked an official of one of them one time, one of the major lines, "Why not?" Well, he said, "We didn't think it was necessary in the beginning, and it would be too expensive to do it now." How are we going to get away from this?

Even in your most sophisticated, Kennedy Airport, Lord help you if you have to transfer from one airline to another. It is not easy.

Dr. STEVER. Mr. Chairman, I would like to speak to this point on airports in two ways. Of course, there are some aspects of airport development which, because of the safety responsibility of the Federal Government, they must control, and these are the number and location and size of runways, which of course do play an important part in the total planning of an airport.

And in that part, I see no escape by Government for being in the operation and in the business of planning those airports. On the other aspect, it is my feeling that while the local competition and local ingenuity and originality is a very important thing, I think that the Government has a role there of communication, giving the good ideas, and in fact developing some good ideas to be available for that aspect.

Dr. BISPLINGHOFF. Well, I think a handbook of elementary principles in airport design might be put out by one of the Federal agencies.

Mr. HECHLER. It could be used by local architects in cities that were struggling with this problem.

Chairman MILLER. I think you might invite the American Institute of Architects to sit with you on some of this.

Dr. STEVER. That would be an interesting point.

Chairman MILLER. It might be a very interesting point, because as the doctor says, a local handbook would be quite desirable. Well, I want to congratulate you both. Unfortunately I have to run. I am sorry I missed Mr. Lundin.

(Discussion off the record.)

Mr. HECHLER. Mr. Pelly.

Mr. PELLY. Mr. Chairman, first I want to note that when any ordinary member of this committee starts getting out of the jurisdiction of this subcommittee, you reprimand us. But when we have Mr. Miller here we are very glad you brought up that subject.

Chairman MILLER. I don't reprimand you; I just don't want to bring down the wrath of the gods.

Mr. PELLY. But Mr. Hechler does, and we were glad you were here to bring up a subject on which we are vitally interested.

Chairman MILLER. I am not saying it is within our jurisdiction, but I certainly say it is an inescapable part of the aeronautical problem, if we are going to solve it. See, we west coasters can get into some arguments, too. Mr. Pelly is a very valuable member of this committee, and comes from the great State of Washington.

Mr. PELLY. Well, I never get into an argument with my committee chairman, because you always rap me down. I do appreciate the fact that you are interested and you come to our subcommittees and bring up a subject in which we are greatly interested.

Chairman MILLER. I would like to be at all of the subcommittees. If I was an amoeba maybe I could divide myself.

Mr. PELLY. Now, Mr. Hechler, if I could come back to the two very distinguished witnesses. I want to join Mr. Miller in thanking you for your very fine contribution here. Both of you gentlemen referred to the matter of getting engineering talent, new blood into the research programs. This is a subject that interests me a lot, because I have lately been noticing the tremendous interest that young people are showing in the environment, and here we are today talking about research and noise abatement and the clean air and other matters that fall under the jurisdiction of this committee, and if we could only enlist that interest that young people have now in our environment, in this research in doing something about the environment in a practical way, I think it would be very helpful.

I was thinking about the day that the President announced that he was going to proceed with the supersonic transport. This television program reached many millions of people young and old, and it was one of the new type of aircraft that Dr. Bisplinghoff referred to as needed to excite these young people, and yet that very night I listened to a team of commentators and one of them, raising his eyebrows and adjusting his voice to maybe, to imply something, said "So now the rich will be traveling at the expense of the taxpayers."

Well, I don't view it in that light at all. I view it as the fact that, and I am sure you agree with me, that the economic feasibility of this advanced type of transportation will be not one to necessarily carry only the rich, but to anyone who travels now, including students.

And I wonder if you wouldn't agree, too, that the development of this type of new air transportation will certainly keep us supreme in this field of technology which keeps our Nation on top, and helps in the end to alleviate some of the problems of congestion of airports, at least for the time being.

We won't need some planes at least if they are going to pollute the air, if they are going to travel faster.

Dr. BISPLINGHOFF. Well, let me comment on your statement in the following way, Congressman Pelly. I think you have put your finger on a very important turn of events in education. There is a true groundswell among students of science and engineering toward interest in improving the environment, in improving the way we do things on earth, and one of the results of this is an increased interest on the part of our students in science and engineering in transportation itself.

And this can be reflected by the interest we find among other students who study in the field of what might be called aerospace engineering or aeronautics and astronautics. I noted that at MIT within the last 2 years, a much larger proportion of our students have become interested in aeronautics and air breathing and air vehicles in contrast to space than we have had in the past 7 or 8 years, and I think this is simply a reflection of this groundswell that you alluded to right at the beginning of your remarks.

And I would say this is one of the bright spots insofar as our discussions are concerned here, relating to the field of aeronautics and the application of aeronautics to improve transportation. With regard to the SST, I have been an SST supporter for many years. I could only say that it makes sense from a lot of viewpoints, and it makes a great deal of sense from the viewpoint of economics.

It is a good R. & D. investment from the standpoint of a later economic return on investment. I don't know of a better R. & D. investment that this country or any other country could make.

It is going to have a profound influence on commerce between the United States and particularly in the long run the other countries that we have to reach over the vast expanses of the Pacific Ocean.

Mr. PELLY. I wish you had used Seattle to Tokyo rather than San Francisco in the illustration, Dr. Stever, because it is the shortcut route to Tokyo.

Dr. BISPLINGHOFF. If I would have had the proper foresight, I would have done that.

Dr. STEVER. Mr. Chairman, may I add, Mr. Pelly, may I add one thing to what Dr. Bisplinghoff said. First of all, I will reinforce what he said. But one of the important things, I think, one of the important messages to get across to young people who are entering the fields of engineering and science, is that in the case of some of these nuisances, problems, which they see around them in the environment—noise and smoke and so on—alleviation can be accomplished by more and better technology in a society that is interested in doing it. In fact, I can't conceive of our society doing it without better technology.

I think we can have better air transport and not have the nuisance problem grow, the noise and the smoke. And we have already begun to prove it in the business that you mentioned, the 747. While the engines are four times as powerful, on the average, as the existing jets, they are not noisier.

In fact, the whole airplane gives the impression that it is going to come out with the same noise level or less. The same can be said about the smoke problem of aircraft. That can be eliminated. So I really feel that as a country we have got to encourage the young people to—if they want to do something about the nuisances they see about them, the problems of the environment—the way to do it is through the proper application of better science and engineering and technology.

Mr. PELLY. Certainly President Kennedy inspired the American people toward the goal of landing a man on the moon and returning him. With the same kind of leadership to inspire our young people in research and doing something about the environment in this field, I think it would be sufficient.

Dr. STEVER. It would be a tremendous boon to those of us who are at the cutting edge of education.

Mr. HECHLER. Well, gentlemen, I am no expert in the generation gap, but I think what does disturb many young people is the fact that the technology is here in many cases. Yet there are human, political, and bureaucratic stumbling blocks which stand in the way of solving these very serious problems that confront us in questions like the pollution of our environment, and the problem such as you have touched on.

I think you put your finger on it very well in analyzing with refreshing objectivity what had happened to your report, and I like the way you put it. There is a gap here between the things that you have set forth and recommended in this report, and their application.

Dr. STEVER. Yes.

Mr. HECHLER. And despite the good cooperative relationship between DOT and NASA, it strikes me there is still a lack of precision in just exactly where we are going and how quickly we are going to get there—in fact, even where we ought to go first in our priority list. Is there anything——

Dr. STEVER. I agree; yes.

Mr. HECHLER. Is there any clue that you can give us as to how to move a little faster in this atmosphere which in cold weather sometimes gets a little like molasses?

Dr. STEVER. Well, of course, you people are the legislators and you are experts at cutting through and reducing the molasses quality of our environment, and I must say, to me, there are lots of signs of progress. I think you have to keep it up.

You know, it is an interesting thing. It was a very short time ago that nobody in the aeronautical field ever really felt that the noise problem of airplanes would be a serious problem. But all of a sudden the world got interested in it. And as soon as they got interested, progress began to come up. And that is what we have got to do.

We have got to get interest in the solutions being pushed into the system and the system will produce these. The same with the smoke of airplanes. The 747 doesn't smoke, et cetera.

Mr. PELLY. Of course, if I might inject a thought here—and I don't want to compete with the Vice President in attacking the news

media—I think we need some more balanced news reporting. I know as far as the SST is concerned that one of our leading local papers carried the argument of the opposition, and the task force's adverse report. But, they never saw fit to carry the other statement that the head of every airline, major airline in the country was supporting it. And I think they sometimes don't inspire a desire to overcome what you call, Dr. Stever, the widespread mood for not venturing in technology at this time.

I think we need a little better reporting somewhere.

Dr. STEVER. Yes, positive thinking.

Mr. HECHLER. Well, the application of the technology, though, would encourage more people perhaps to get into it, if they could see it being used and see some of the factors that are now discouraging its use brushed aside a little faster.

Dr. STEVER. Yes.

Mr. HECHLER. Youth is always very impatient, but I think they have great reason to be impatient, when you see the way in which some of these problems can be solved with current technology.

But your citation of the way in which we have become awakened to the noise problem brings to mind the fact that the airport problem really is far more complex, even, than you have indicated, Dr. Bisplinghoff, in talking about design. It is a problem of diminishing amount of land in this country.

It is a problem of the loudest voices being heard. I think someone mentioned before this committee last year that we ought to have a little better system of communicating objective facts and making available planning to local communities.

I don't know if that is the answer, but right now those who oppose all action or progress can be heard and they are masters of psychology. They know that if they scream loud and long enough about certain things that they are not going to be done. I think the President put his finger on this when he talked about the silent majority. Even though I happen to disagree with the context in which he placed it, I think there is an area in aeronautics that we ought to direct our attention to.

Dr. STEVER. Mr. Chairman, along that point every now and then I see a favorable sign. It is in connection with the problems that have arisen in the New York area, with respect to the tremendous job, the difficulty they have had in getting the fourth jetport. I saw in the papers the other day that the FAA is now changing its approach to try to solve the airport problems of the New York metropolitan area by a different approach, not to have a fourth jetport but to make greater use of smaller fields, make greater use of the STOL and VTOL that we are so anxious to have.

But that very problem, the increased tension in the New York area is, I think, making other communities more aware that they have got to go to a systems approach. This morning or in the very recent past I saw in one of our Pittsburgh newspapers where Pittsburgh is also planning a major improvement of its airport.

But in addition to that the people thinking about the airports in Pittsburgh have now come up with a recommendation that the airport authority, the county, make greater use of the three or four other airports around and begin to plan them into the system. So here is progress already in greater communication in airport planning.

Mr. HECHLER. The preamble to the Constitution starts off, "We, the people of the United States, in order to form a more perfect Union." In the field of aviation and aeronautics, one would think that the decision were 100 percent by and for the benefit of one community. Yet we have entered an age where people from 50 States and many foreign nations use these airports, and depend on the safety, location and convenience and the other factors that are so important to everyone.

Dr. BISPLINGHOFF. Mr. Chairman, as a scientist and engineer I am not very comfortable with our record. However, in dealing with some of the undesirable effects of technology on society, and my students remind me of this all the time, that the engineering scientist hasn't been very responsible in this connection.

We must always remember that there is an economic tradeoff here. If you do very much to change the effect on the environment then it is going to cost money. If you do quite a bit it is going to cost quite a bit of money, and in almost every case, including the noise produced by aircraft, there is a very large economic tradeoff. And unfortunately, we somehow or other have not had the ability to take these actions ourselves. We have had to wait for this long feedback loop to take over from the people, almost up to the Congress, and we have in case of aircraft noise had to rely or are going to rely on Federal regulations coming down from the top.

I am not very comfortable with this, myself. I think it is one way to work, but I believe that the scientist and engineer and perhaps the universities may be able to exert a considerable influence on this in the future.

But we have to get some smaller feedback loops in the system and some shorter reaction times than we now have. I am not sure that I can tell you how to do this, but it may be necessary to do it within the executive branch of the Government in some way.

But we have to find, I think, a better way of dealing with the long-term undesirable effects of technology that we now have.

Mr. HECHLER. Well, I agree with you 100 percent. If Mr. Pelly would allow me to get out of the jurisdiction of our committee again——

Mr. HECHLER. Incidentally, I am very pleased that you brought this up in the presence of the chairman, because it indicates that we are going down the right line.

But just as a side observation, in the area of coal mining we have run into this whole problem of the economic incentive producing mining machines which dig out coal faster, and damage the lungs of the miners more. This is an analogous byproduct of technology.

But when we get this back to the committee's jurisdiction, how in the area of aeronautics can we proceed, both in Congress and the executive branch, to try to minimize the straight economic incentive or fallout of technology, and try to make sure that we can plan in line with national goals and priorities, and also the protection of our environment?

Are there any other suggestions you have along those lines?

Dr. STEVER. Well, I think the pressures from the people are getting so great that everybody, every technical person, every administrator, every legislator is going to have to respond, and put into the equations that Dr. Bisplinghoff mentioned the environmental factor, as well as the economic.

Mr. HECHLER. There is one factor that I have repeatedly mentioned before this committee and that is leadership.

Mr. STEVER. Yes, sir.

Mr. HECHLER. It is highly important to enunciate a national goal that will take into consideration the very things we have been talking about.

Dr. BISPLINGHOFF. I think our democratic process works well in this connection. The only thing that I find wrong with it is the long feedback time, and I think with new technologies developing, we are going to have to find a shorter feedback time.

Mr. HECHLER. I rode back on the plane on Sunday with a retired colonel who was telling me about his experiences in Ethiopia—oh, how wonderful it was, that he was able to bring the Emperor out to the edge of town to talk about a new housing development that they were planning on erecting.

The Emperor had asked two or three questions about it, and finally had said, "OK, let's go ahead," and then they went ahead.

And, of course, in a society like that, there are many other problems, not to mention palace revolutions that you have. You are not suggesting that we go that course, are you?

Dr. BISPLINGHOFF. No, sir.

Mr. PELLY. I would just like to comment that I think this has been a very refreshing and very objective and constructive session this morning, and I want to thank the two witnesses for making it that way.

Mr. HECHLER. Yes, I certainly share those sentiments.

Along the lines of a question I asked Mr. Lundin earlier, can you assist NASA in compiling some data on just where we stand insofar as the young engineers interested in aeronautics are concerned?

We have made several comments about it, but I think we ought to tie this down scientifically, if you will, in terms of the numbers, average ages, and what the future holds, and what other things that could and should be done in order to insure that the reservoir is replenished.

Dr. BISPLINGHOFF. Yes.

Mr. HECHLER. Are there any observations or comments that either of you gentlemen would care to make?

If not, we certainly thank you, Dr. Bisplinghoff and Dr. Stever.

The committee stands adjourned until tomorrow at 10 a.m.

(Whereupon, at this time the committee adjourned, to reconvene at 10 a.m. on Wedneday, December 10, 1969.)

(Dr. Bisplinghoff submitted the following material on the problems of encouraging younger personnel to become associated with the field of aeronautics.)

NATIONAL ACADEMY OF ENGINEERING,
Washington, D.C., January 13, 1970.

Hon. KEN HECHLER,
Chairman, Subcommittee on Advanced Research and Technology, Committee on Science and Astronautics, Rayburn House Office Building, Washington, D.C.

DEAR KEN: When Dr. Stever and I appeared before your Committee on December 9, you asked for any additional information we might have on the question of education of aeronautical engineers in this country.

We share your concern over the increasing average age of engineers engaged in the research, development, and engineering of atmospheric flight vehicles. This coincides with our observations of a general decline over the past decade in the number of younger people entering into aeronautical engineering.

It is doubtful that this trend can be altered significantly unless some of the underlying causes can be changed. You will recall that we mentioned at least three factors which we feel have contributed to this unfortunate situation. Briefly, these are the great upsurge in support for space research and development in the early and mid 1960's, the concurrent reduction in government support at universities for research and development on atmospheric flight vehicles, and the decline in the number of new aricraft types developed in the United States.

Despite what appears to be a bleak picture, there may be a bright spot emerging. Data available at MIT indicate that within the last two years a much larger proportion of our engineering students have become interested in aeronautics and air vehicles as compared to space. This is in contrast to the trend established over the previous seven or eight years.

I believe this resurgence in aeronautics can be accounted for, in part at least, by the increasing interest of science and engineering students in improving our national environment and the way we do things on earth. Hence, air pollution and air transportation, to name only two current major problem areas, represent a challenging opportunity for the young aeronautical engineer to make a significant contribution to the needs of the nation.

Perhaps greater visibility on the problems and challenges of civil aviation and its importance to the national welfare could still influence even more students to embark on a career in aeronautical engineering. In general, I believe, the young students of today must be shown that careers in science and engineering offer one of the best opportunities for them to make a real contribution to the betterment of the quality of life.

Dr. Stever and I hope this information will be useful to you in your continuing effort to strengthen the technological base of the nation.

Sincerely,

R. L. BISPLINGHOFF, *Chairman.*

AERONAUTICAL RESEARCH

WEDNESDAY, DECEMBER 10, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 2325, Rayburn House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The committee will be in order.

This morning we will hear from Mr. Fred W. Garry, vice president and general manager, Aircraft Engine Technical Division, General Electric Co. of Cincinnati.

Good morning, Mr. Garry. Do you have a prepared statement you wish to present to the subcommittee?

Mr. GARRY. Yes, sir; I do.

Mr. HECHLER. You may proceed.

STATEMENT OF FRED W. GARRY, VICE PRESIDENT AND GENERAL MANAGER, AIRCRAFT ENGINE TECHNICAL DIVISION, GENERAL ELECTRIC CO. OF CINCINNATI, OHIO

Mr. GARRY. I am Fred W. Garry, vice president, General Electric Aircraft Engine Technical Division. I have been with General Electric since 1951 and my responsibilities encompass all phases of aircraft engine design for the General Electric Co., beginning with research and development and extending on through development of the engines, the qualification and postsales service.

Mr. HECHLER. Excuse me, Mr. Garry. Without objection, I would like to place in the record your biographical statement.

Mr. GARRY. All right, fine.

Mr. HECHLER. You may proceed.

(The document follows:)

FREDERICK W. GARRY, VICE PRESIDENT, AIRCRAFT ENGINE TECHNICAL DIVISION, GENERAL ELECTRIC CO., AIRCRAFT ENGINE GROUP

Mr. Garry graduated from Rose Polytechnic Institute with a B.S.M.E. degree in 1951 and received a Doctor of Engineering degree from Rose Polytechnic Institute in 1968. He joined the General Electric Company's Flight Propulsion Division in 1951 and has served in a series of component and engine design positions. Following his appointment as Design Manager of the Mach 3 J93 engine, he became Manager of the CF700 Turbofan Project and, shortly thereafter, attained responsibility for the CJ610 Turbojet Program as well. He was appointed Manager—Engineering, Production Engines, 1966; General Manager—Engineering, 1967; and was elected Vice President October 28, 1968.

Mr. Garry's responsibilities include the engineering and technical program management for all of the General Electric Aircraft Engine Group's commercial

engines, as well as for military engines, and land based engine applications. Mr. Garry's aeronautical background and current activities are extensive including: previous military experience in the US Marine Corps as a Naval Flight Training Instructor and pilot of fighter aircraft, current member of the Board of Directors of Greater Cincinnati Airport, member of the SAE (Society of Automotive Engineers), Aerospace Council, member of the Executive Committee of the Aerospace Technical Council of the Aerospace Industries Association. He maintains an interest in private aircraft flying; as an active commercial rated pilot, owns a private aircraft, and is a member of the AOPA (Aircraft Owners and Pilots Association).

A native of Stratford, Connecticut, Mr. Garry now makes his home with his wife, Betsy, and their two children, in Cincinnati, Ohio.

PREPARED STATEMENT OF FRED W. GARRY, VICE PRESIDENT AND GENERAL MANAGER, AIRCRAFT ENGINE TECHNICAL DIVISION, GENERAL ELECTRIC CO.—CINCINNATI

I. INTRODUCTION

The Aircraft Engine Group has produced more jet engines for the United States Government than has any other manufacturer. We have been producing jet engines since 1942 when we built the first American jet engine. The Company has now produced over 60,000 aircraft gas turbine engines including the well known J79 used in the multi-service F-4 Phantom, and the T64 and T58 engines, used in a wide variety of Navy, Army, and Air Force helicopters. In addition, the Company has experience in the commercial engine business with the CJ850 engine series currently in service on the CV880 and CV990 aircraft. The applications of our engine range from supersonic aircraft to Navy patrol gun boats.

As a part of these engine programs, the Aircraft Engine Group has carried out extensive research and development related to engine noise abatement since the mid 1950's. From this period of time to the present, the Aircraft Engine Group has developed extensive indoor and outdoor noise testing facilities. These noise resources are located at the Research and Development Center, Schenectady, N.Y.; far field noise test facilities at Peebles, Ohio; laboratory facilities at Evendale, Ohio; and ground and flight test noise facilities at General Electric Flight Test Center, Edwards AFB, California (Figures 1 & 2).

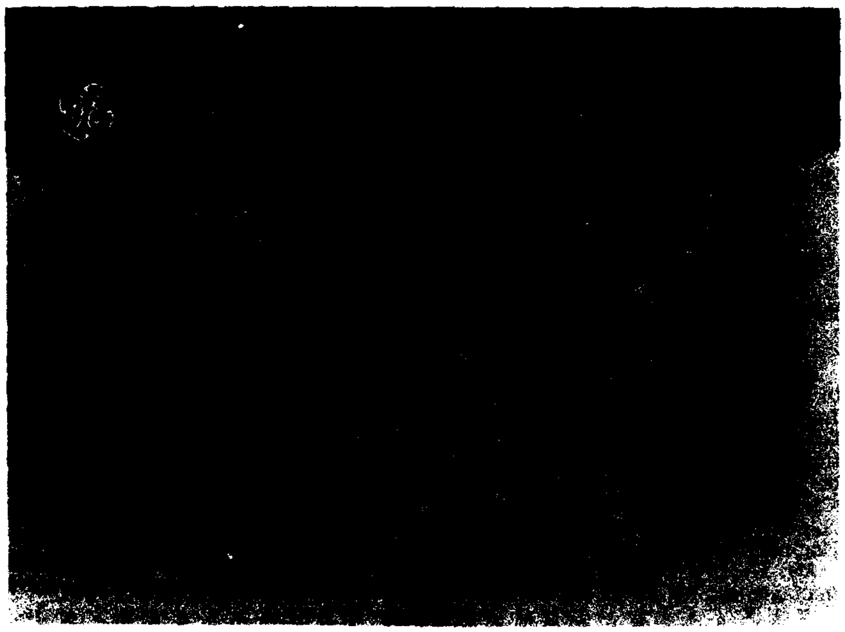

FIGURE 1

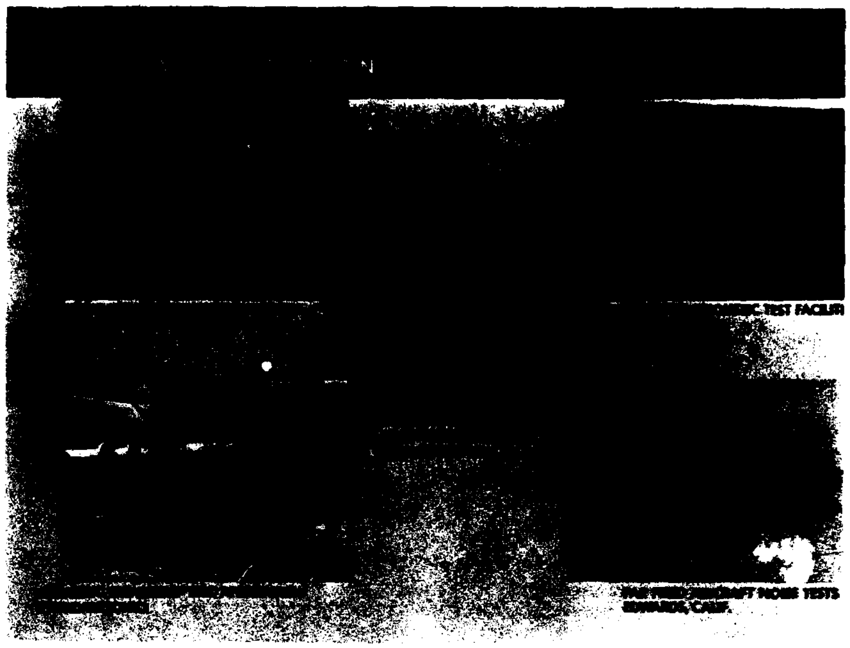

FIGURE 2

II. PERSPECTIVE

In a few days we will enter a new decade, the seventies which promise many great things for air transportation. The new Jumbo Jet airliners (DC10, 747, L1011, A300) will become commonplace by 1980. The new Jets will carry up to 500 persons compared to about 150 in today's large airplanes. Powerful turbofan jet engines of 40,000 and 50,000 pounds thrust, compared to about 12,000 to 20,000 pounds thrust of engines in today's commercial airplanes, represent a most difficult technological job in restraining their sounds to not only be no noisier than today's airplanes, but to be even quieter.

For a number of years, we have been working hard to determine exactly what causes the noise from a turbofan engine, and secondly, to evaluate many ideas to alleviate that noise. We do not know how to make a powerful turbofan engine noiseless; but we have made progress, stimulated by Government agencies and the airlines, in understanding and reducing aircraft engine sound levels and, now the Experimental Quiet Engine contract from NASA, we are hopeful that further progress can be demonstrated, the results of which will be available to all aircraft engine and airplane manufacturers.

III. PROGRESS IN SOUND REDUCTION FOR HIGH BYPASS JUMBO JET ENGINES

Before proceeding to a discussion of the Quiet Engine Research I'd like to provide some perspective on the state-of-the-art of low noise technology to be incorporated into the second generation jet airliners. The General Electric Company has been selected to provide new type engines for the two new Jumbo Jets, the DC-10 and the Sub A300B. Since we built the first American jet engine a number of years ago, my Company has had a record of achievement in innovation regarding the design of aircraft engines; and in 1964 we proposed a new engine concept for the C-5 airplane, the so-called high bypass engine. Not only did this new kind of aircraft engine show, in some 5,000 engine hours of successful flight, that high levels of thrust and new low levels of fuel consumption were possible, but the engine sound (with a minimal of special attention to noise reduction features) was much lower than what might be expected from its size alone. Furthermore, the quality of the engine's sound and its fly-over characteristics were less annoying. In the past year, we have designed and tested a

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commercial version (CF6) of this high bypass engine. This commercial design, however, also included features that our research has proven to reduce noise. Specific among these low noise design features are:

(1) The high bypass engine concept where 80% of the thrust comes from the air going through the 7 foot fan, developing the thrust by using more jet air at lower jet velocity than the engines now in service which have fans that use smaller quantities of air at high jet velocities.

(2) A minimum of noise interaction effect between the stationary and rotating components by eliminating inlet guide vanes, axially spacing the outlet guide vanes away from the rotor; and providing a high ratio of outlet guide vanes to rotor blade number (Figure 3).

(3) The use of a special sound absorbing material developed by General Electric, in the fan ducts (Figures 3 and 4).

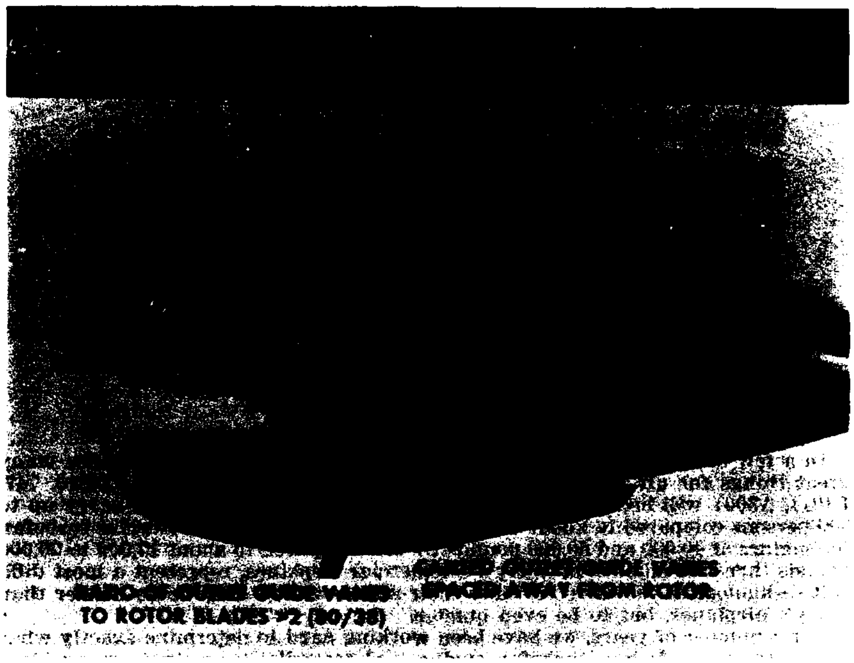

FIGURE 3

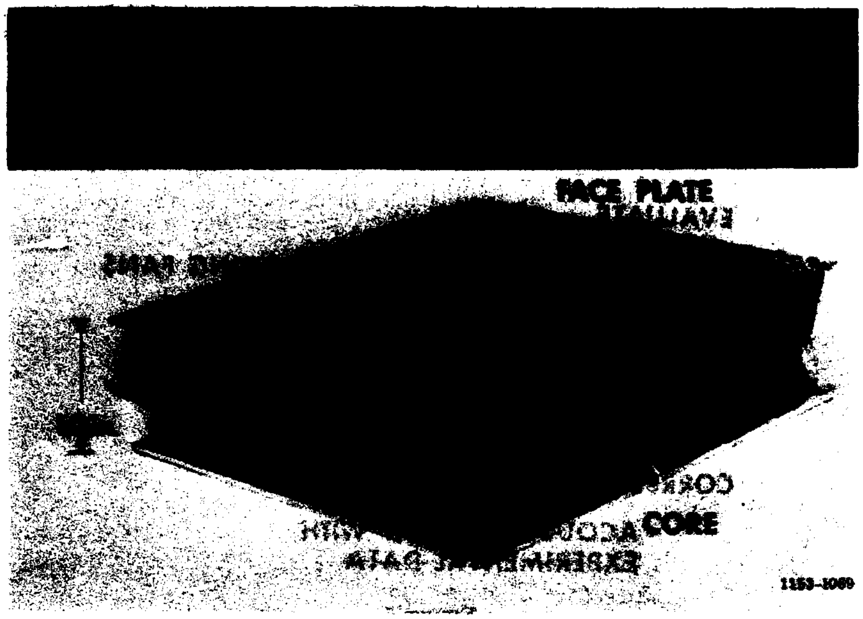

FIGURE 4

Based upon ground static scale model and full scale tests of the CF6 engine design, it is anticipated that a noise reduction of the order of 10 PNdB will be realized, as compared to a design not utilizing noise reduction design features. This amounts to approximately a ninety percent reduction in noise energy from the turbofan engine system.

I would like to play a short sound tape that demonstrates the progress we have made in making our new aircraft engines quieter than engines on airplanes operating at airports today, even though the new engines are much more powerful and would otherwise be far more nosier than today's aircraft engines. In the tape which you will hear, the message is simple—we have used the technologies which I just described, to make new and powerful aircraft engines quieter than old design engines now in service. (Tape).

IV. NASA EXPERIMENTAL QUIET ENGINE PROGRAM

General Electric's portion of the NASA Experimental Quiet Engine Program is a fan source noise reduction research program. It is a technology program, not a powerplant product development, per se, but it will obviously have significant implications for further turbofan powerplants. It is anticipated that the results of this program will enable a 15 to 20 PNdB noise reduction over current day commercial aircraft.

This $18.7 million two phase program, initiated in July 1969, will cover a time-span of thirty-eight months. By the fall of 1972, all scale model and full scale fan components, as well as engine testing, will have been completed.

The design phase (initiated mid 1969) is nearing completion and is on schedule for completion by December 31, 1969. The Phase II (option) is scheduled for initiation in January 1970 and will carry the program through the testing of components and full scale engines. The funds allocated and planned for the program are believed adequate to support the contracted program.

Important technical objectives of the Experimental Quiet Engine Program are illustrated by Figure 5. These objectives are noise evaluation of low tip speed versus low aerodynamically loaded fans; noise evaluation of specific fan tip features designed to reduce fan source noise generation; and noise evaluation of acoustically treated full scale turbofans. An additional technical objective throughout the program will be the correlation of acoustic theory with the experimental test results.

TECHNICAL OBJECTIVES

EVALUATE

- LOW-SPEED AND LOW-LOADING FANS
- FAN SOURCE NOISE REDUCTION DESIGN FEATURES
- ACOUSTICALLY TREATED TURBOFAN ENGINES

CORRELATE

- ACOUSTIC THEORY WITH EXPERIMENTAL DATA

FIGURE 5

Experimental data already collected by GE seem to indicate that low speed fans exhibit a more pronounced pure tone noise, whereas low-aerodynamically-loaded fans seem to exhibit somewhat more pronounced broadband noise levels as a function of frequency (Figure 6). The Experimental Quiet Engine Program will provide the means to further analyze these indications, and to update and increase our understanding.

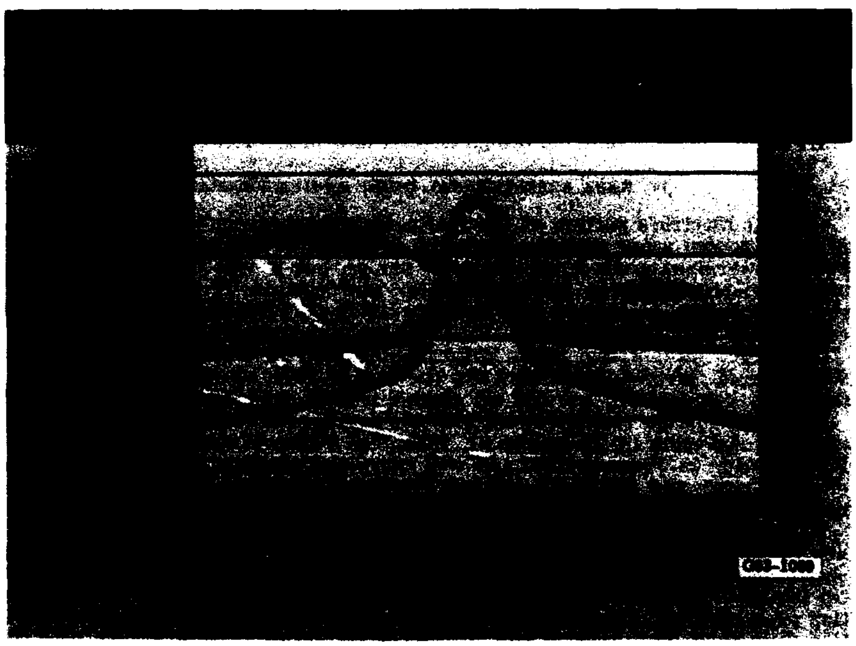

FIGURE 6

As a part of the design phase, the design of three different fans has been completed. All of these designs contain low noise design features indicated by Figure 7. Based on test results from the program, a fourth fan will be designed and fabricated in 1971. This latter fan will incorporate the more significant design features that have shown promise of noise reduction. All of these fans are designed to operate in conjunction with the TF39/CF6 core engine, thus making up a full scale turbofan engine system.

FIGURE 7

The different characteristics of the three fan designs are illustrated by Figures 8, 9, and 10. Two of the fans are relatively low tip speed. The third is a low aerodynamically loaded fan. Taken together, the three fan designs will span a range of tip speed and aerodynamic loading. The effects of these parameters (as they relate to blade passing frequency and broadband noise), therefore, will be evaluated in Phase II along with other parameters such as blade number, blade-vane ratio and blade-vane-spacing. In addition, the fan designs contain acoustic treatment in the fan ducts enabling Phase II evaluation of the fans with and without the acoustic treatment (Figure 11).

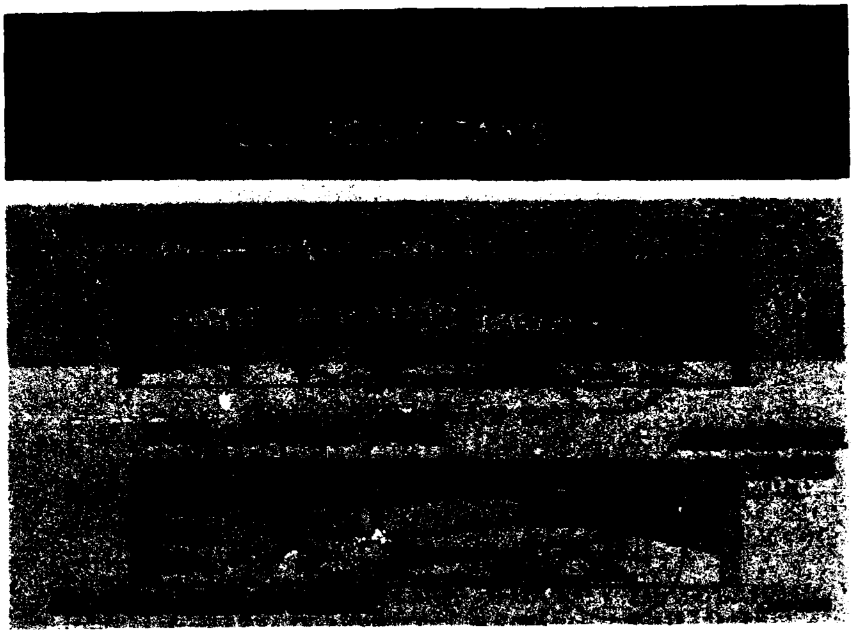

FIGURE 8

FULL SCALE FANS

FAN	A	B
DESIGN TIP SPEED, fps	1,100	1,100
DESIGN PRESSURE RATIO	1.5	1.5
BLADE/VANE RATIO	40/90	26/60
SHROUDS	TIP	NO

FAN	C
DESIGN TIP SPEED,fps	1,550
DESIGN PRESSURE RATIO	1.6
BLADE/VANE RATIO	26/60
MID-SPAN SHROUD	

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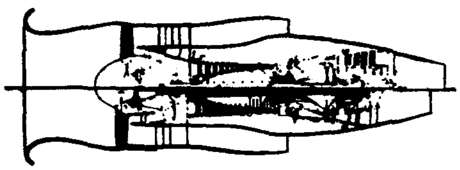
FIGURE 9

QUIET ENGINE PROGRAM



LOW SPEED HIGH LOAD FANS (A&B)

HIGH SPEED LOW LOAD FAN (C)

FANS	A	B	C
DESIGN TIP SPEED, fps	1100	1100	1550
DESIGN PRESSURE RATIO	1.5	1.5	1.6
BLADE/VANE RATIO	40/90	26/60	26/60
SHROUDS	TIP	NONE	

G32-1069

FIGURE 10

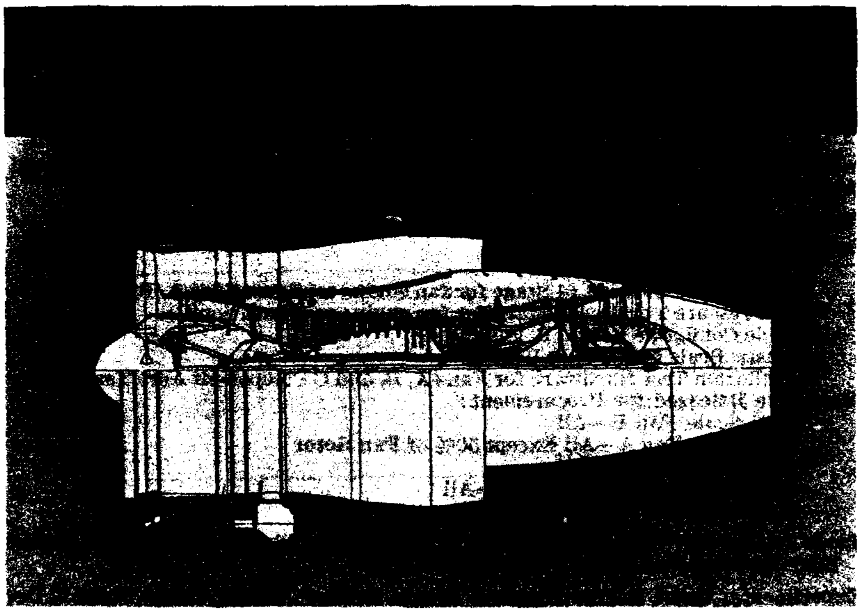


FIGURE 11

Concurrent with the full-scale fan design, the program plan calls for carrying out a comprehensive acoustic scale model fan design wherein unique noise reduction features are incorporated. Among the noise reduction design features (illustrated by Figure 12) are:

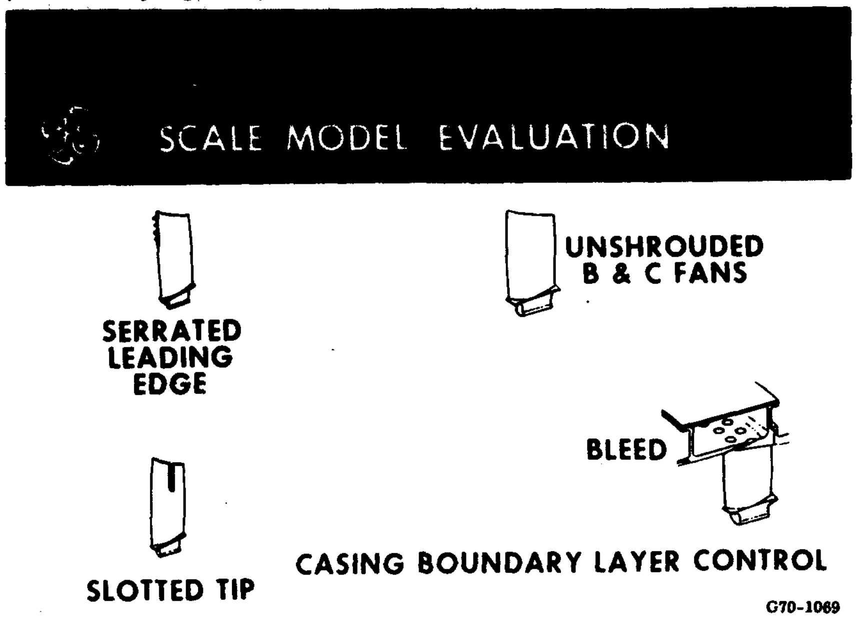


FIGURE 12

Serrated fan blade leading edges.
Slotted tip blades.
Casing boundary layer control, tip bleeding.

Other ideas that develop as the program proceeds can become additional program options.

Phase I status

Design Completed:
- Full Scale Fans A, B, and C.
- Low Pressure Turbine (4 Stage for fan engine configurations A/B).
- Low Pressure Turbine (2 Stage for fan engine configuration C).
- Engine Configurations A, B, and C.
- Acoustic Scale Model Test Vehicle.
- Installation Test Hardware for Fans A, B, and C Component Aero Tests.

Hardware Released for Procurement:
- Full Scale Fan B—All
- Full Scale Fan A—All Except 50% of Fan Rotor
- Full Scale Fan C—60%
- Acoustic Scale Model Fan B—All
- Acoustic Scale Model Fan C—All

Texts In Process: Subsonic Wind Tunnel Apparatus Checkout Test for Leading Edge Serrated Fan Blade Configuration

Experimental Quiet Engine Program Design Review: NASA/Lewis Phase I Design Review, December 8, 9, 1969

Phase II of the program will include: the completion of procurement of the full scale hardware; completion of procurement of the half scale model fan hardware; aerodynamic and acoustic testing of the fans as components; and acoustic testing of the turbofan engines.

FIGURE 13

The three full scale fans will be first aerodynamically tested at General Electric's full scale fan test facility at Lynn, Massachusetts (Figure 13). The fans will then be delivered to NASA-Lewis for acoustical test in the Lewis Fan Test Facility.

The fourth full scale fan will be designed, fabricated, and aerodynamically tested in the Lynn facility.

In parallel with the full scale fan component aerodynamic and acoustic evaluation at the NASA-Lewis, the noise design tip features will be evaluated in approximately 50 percent scale model at the Peebles, Ohio far field acoustic test facility (Figure 14).

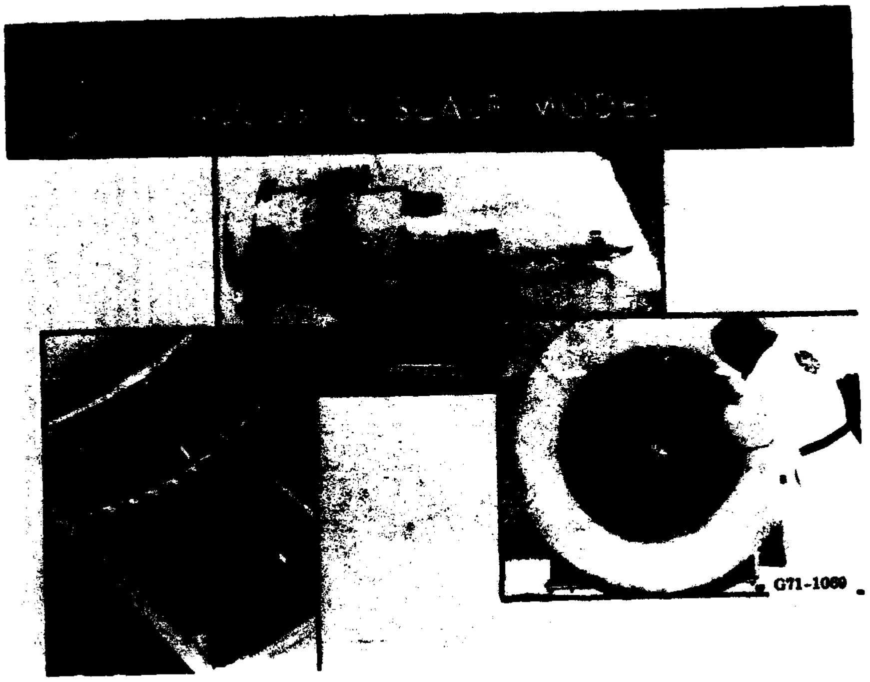


FIGURE 14

The final portion of the program will include the aero/acoustic evaluation of three full scale fans installed on one of two experimental engines at General Electric's full scale, far field acoustic facility at Peebles, Ohio (Figure 15). During this evaluation program, it is anticipated that several acoustic modifications will be made to the fan configurations, based upon analysis and results from other portions of the overall program. Extended duct acoustic treatment also will be evaluated during this full scale test program. Correlation of acoustic theory and experimental data will be accomplished.

A key factor in the program is the use of the TF39/CF6 core engine. Use of the fully-developed, proven TF39/CF6 core will make possible the concentration of development effort where it belongs—on fan noise reduction. The proven core will allow quick turn-arounds and no disruption in testing activities, as might be encountered with an undeveloped core. It will also permit operation of the fans in a realistic engine/nacelle environments. All of the factors of the installed engine noise spectrum, inlet, fan, turbo-machinery, exhaust, etc., is thereby measured and the need for other nacelle or engine treatment established.

Following the completion of all fan development and engine testing, one of the test engines will be refurbished, packaged and shipped to the NASA-Lewis Research Center for further testing and evaluation. The fan to be installed on this engine will be selected by the NASA Project Manager from the configurations developed under this contract.

One additional benefit of the Quiet Engine Program, which should be of interest to all, is the preliminary design study of a flight design high bypass engine which GE will conduct near the end of the program. This design study will incorporate the promising noise reduction features developed and experimentally evaluated in the Quiet Engine Program. These data will be supplied by NASA to all engine manufacturers and should point the way to much quieter engines in the future.

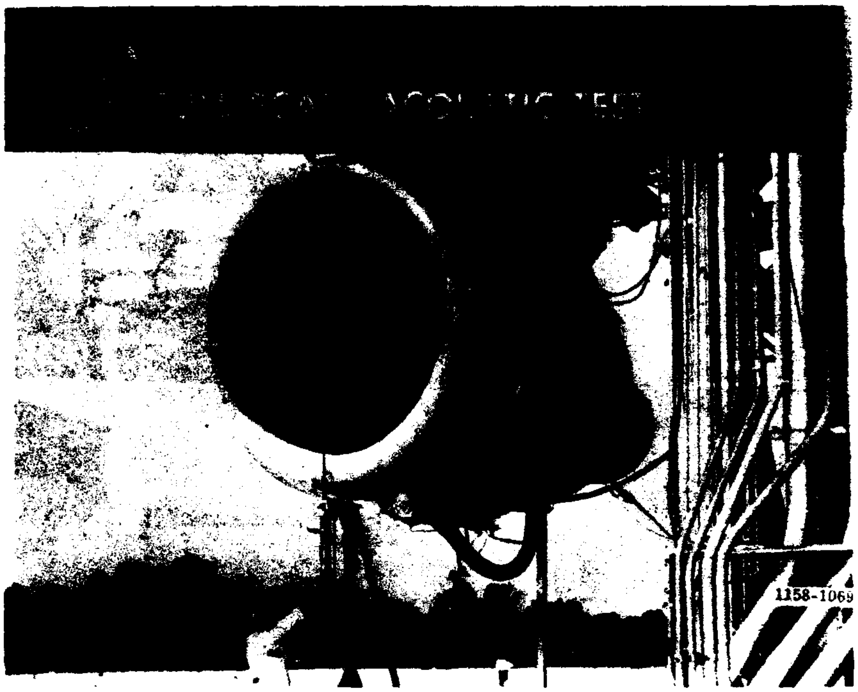


FIGURE 15

V. RELATED R&D NOISE REDUCTION PROGRAMS AT GENERAL ELECTRIC

FAA fan noise prediction program

The objectives of the 24-month General Electric cost shared program to be concluded in July 1970, are to develop and verify advanced compressor/fan noise prediction methods and to demonstrate noise prediction and reduction on fan vehicles typical of modern design technology. The work is to be accomplished in seven interrelated phases.

In Phase 1, the relationships which define the fundamental noise generation and transmission mechanisms have been identified and related to the characteristics of acoustic wave motion. Prediction techniques which are based only on the aerothermodynamic and geometric characteristics of fan/compressor turbomachinery have been developed. These techniques are based solely upon analytical description of turbomachinery aerodynamics and, unlike all previous prediction techniques, do not require empiricism of unrelated noise data to enable accurate predictions.

Phase 2 has shown accurate prediction of noise data from six fan/compressor vehicles ranging in size from six inches to 93 inches in diameter. Figures 16 and 17 show two of the large scale vehicles tested. The prediction method is highly accurate, as shown by the test data on the TF39(GE1/6) development vehicle, (Figure 17).

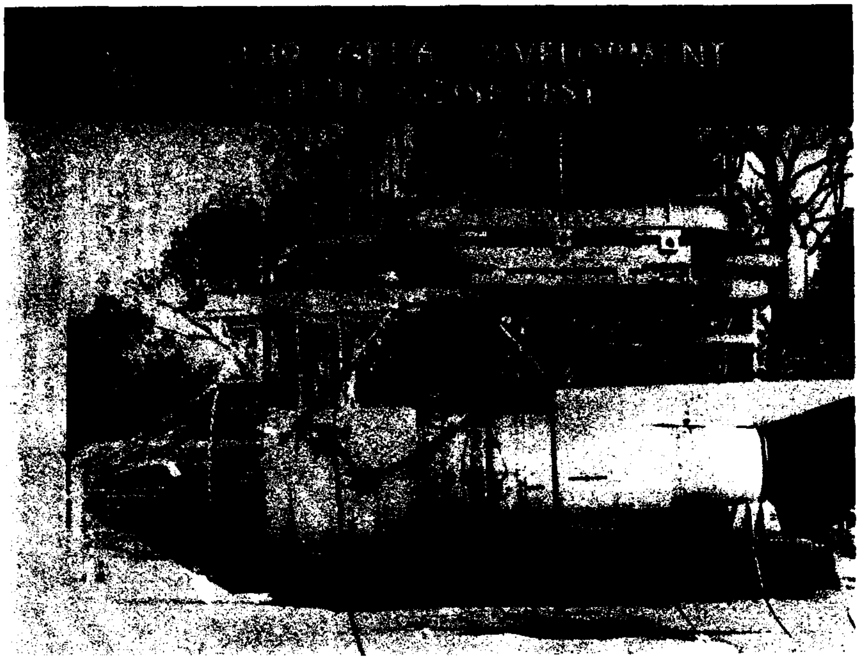


FIGURE 16

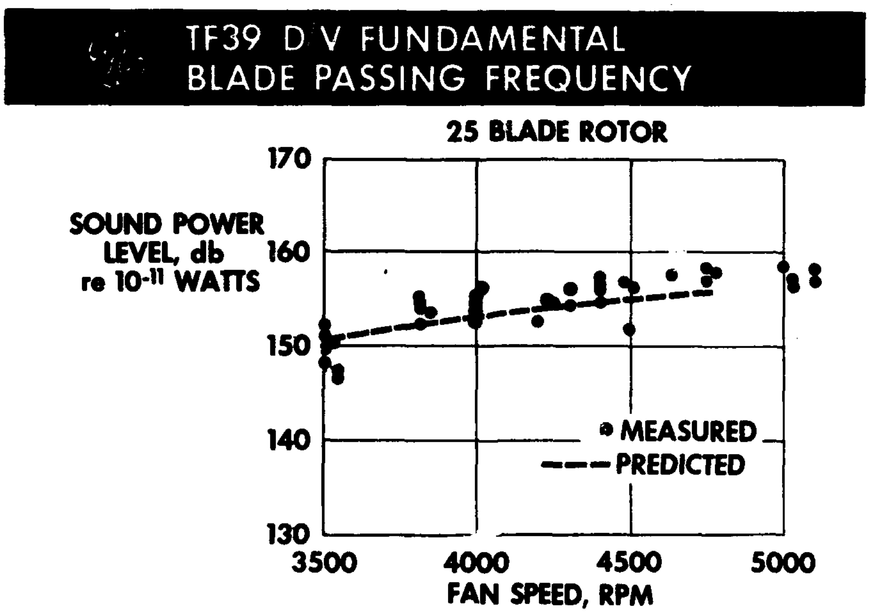


FIGURE 17

Phase 3 will provide verification of the prediction techniques on a late model advanced supersonic tip speed, high bypass ratio, fan vehicle. The data from this vehicle have already been taken.

Phase 4 is an analytical phase which is extending the basic prediction technique to allow evaluation of specific design parameters on fan noise. This phase will enable accurate trade-off studies to be made considering the effects of blade-vane spacing, numbers of blades and vanes, tip speed, blade wake control, and inlet choking.

Phases 5 and 6 involve a series of experiments designed to demonstrate the accuracy of the prediction technique on key fan design parameters and specific noise reduction techniques which can be accomplished within basic fan design parameters.

Tests have already been completed which demonstrate the effectiveness of the prediction technique in accurately forecasting the measured noise level improvements which can be achieved by proper selection of vane and blade numbers in a modern fan vehicle. Other tests to be run include evaluation of such parameters as; vane-rotor blade spacing, blade loading, inlet guide vane incidence angle, blade wage control, swept rotors, refraction of sound through fan discharge exhausts, and the wave cancellation/reinforcement phenomena associated with propagation of acoustic waves from a fan. In addition, an extensive test program is being conducted on a two-dimensional cascade to derive the wake vortex characteristics which control the white noise generated by rotating fan stages.

Phase 7 will exercise the prediction technique on a series of turbojet and turbofans, not previously tested in the program. The additional correlations will be performed to provide assurance that the prediction technique is comprehensive and can accurately be applied to a wide variety of fan designs and sizes.

When completed, the program will enable the engine designer to more accurately assess parameter trade-offs in the design phase of a new engine.

NASA Lift Fan Noise Research

The following program summaries are based on funded programs by NASA to further research in lowering of noise levels in high bypass lift fan systems for STOL and V/STOL commercial transports.

1. *Lift Fan Noise Reduction Studies.*—A nine-month program was conducted to evaluate noise reduction methods in terms of their effects on lift fan design. Two lift fans were used as design points. These fans were analytically modified to study acoustic reduction by trade-offs in fan pressure ratio, tip speed, rotor-stator spacing, number of blades and vanes and the use of various types of acoustic materials.

The basepoint fan has a 500 feet sideline noise of 119 PndB. The quiet version of this fan has a 500 feet sideline noise of only 99 PNdB, a reduction of 20 PNdB. The fan lift is unchanged. The fan diameter is increased by one inch, the fan weight is increased by 17%, and the fan thickness is increased by three inches.

2. *Lift Fan A & B (LF336 A & B) Noise Measurement Program.*—Noise measurements were taken on Lift Fan A (.25 chords spacing). (Figures 18, 19, and 20), and the Lift Fan B (2 chords spacing). Noise predictions were made prior to the test.

The predicted and measured noise levels agreed and thus substantiated analytical noise prediction techniques. The change in spacing decreased 500 feet sideline noise by 7 PNdB, (Figure 21).

3. *Lift Fan C (LF336C) Noise Measurement Program.*—Hardware is now in manufacture with tests to begin December 1969. The program will investigate effects of vane configuration, vane number, spacing, acoustic exhaust duct treatment, and acoustic treated exit louvers, (Figure 22). Noise predictions for each configuration have been made prior to test.

Noise estimates predict a 14 PNdB reduction will be demonstrated at the 500 feet sideline between the configurations A & C Lift Fans. Tests will substantiate this reduction by March 1970. Additional reductions could be obtained by blade number increase and by additional acoustic treatment beyond the Lift Fan C test configuration.

4. *Advanced Lift Fan Acoustic Design.*—The preliminary lift fan configuration for a future STOL and V/STOL transport demonstration will have 90 blades, high vane/blade ratio, 2 chords axial spacing, and will incorporate acoustic exhaust duct treatment and acoustic treated exit louvers.

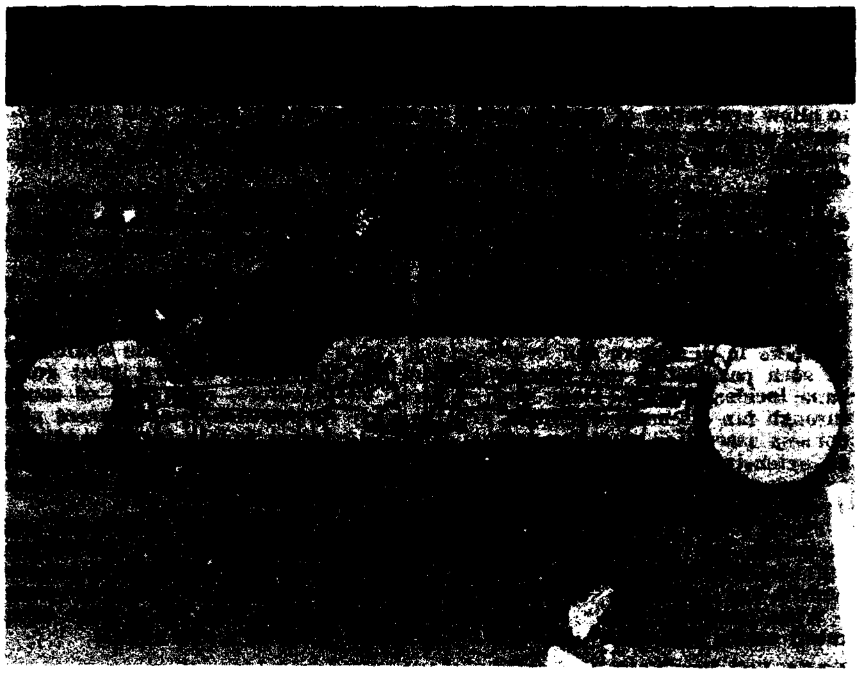


FIGURE 18

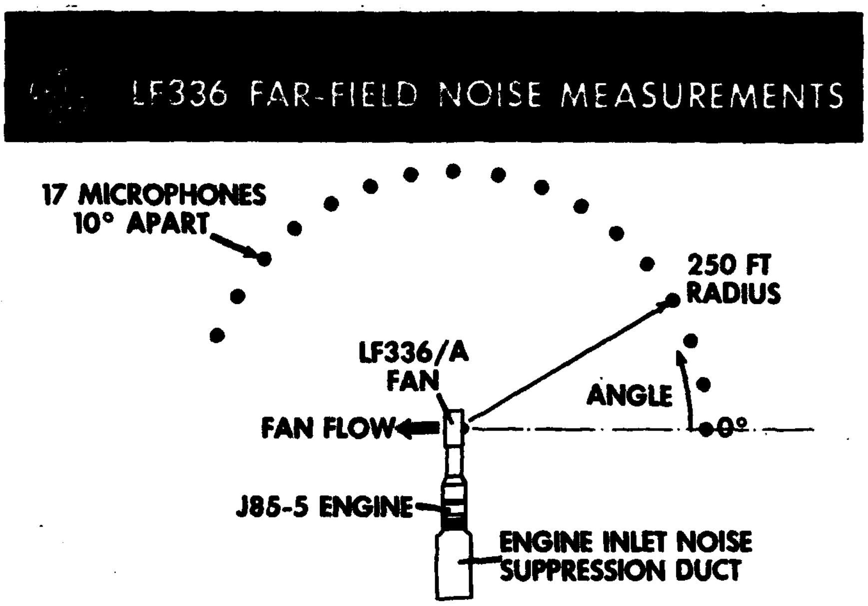


FIGURE 19

FIGURE 20

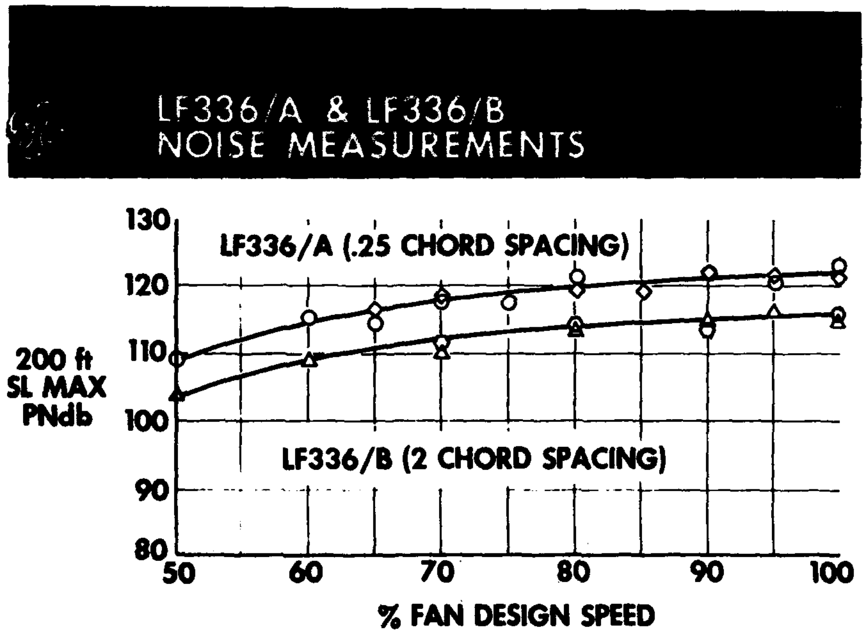


FIGURE 21

LF336-C ACOUSTIC TESTS

TEST NO.	VANES	SPACING	ACOUSTIC TREATMENT	ACOUSTIC LOUVERS
1	45	1	NO	NO
2	90	1	NO	NO
3	90/45	1	NO	NO
4	90/LEAN	1	NO	NO
5	BEST	1	YES	NO
6	90/LEAN	5	NO	NO
7	90	2	NO	NO
8	BEST	2	YES	NO
9	BEST	1	YES	YES

FIGURE 22

Preliminary design studies will be conducted to evaluate the noise level of the selected configuration, and to evaluate the use of an additional acoustic duct splitter in the exhaust and inlet. Lift Fan C test results will be factored into the final fan configuration prior to start of detail design.

Basic analytical and experimental research on jet noise and fan noise is carried out at the Schenectady Research and Development Center, including programs sponsored by NASA Headquarters in Washington. This effort aims at detailed understanding of mechanisms of noise generation, transmission and suppression, so that resulting technology can be used in improving design methods of noise control. Extensive acoustic test facilities have been developed, including the FAA—sponsored Scale Model Freon Compressor Facility, an electronic simulator for fan noise transmission and a hydraulic simulator for fan rotor blade—stator vane interaction noise.

To carry out engine noise reduction design effort effectively, one must first provide the engine designer with adequate "yardsticks" by which the low noise engine designs can be measured, as the designs are conceived. To develop such "yardsticks" involves the recording of noises as they are heard by people at ground level under the flight paths of aircraft, and subsequently subjecting groups of people to these noises to determine their psychoacoustic response (subjective rating), (Figure 23).

For the past several years, General Electric has carried out a substantial flyover noise program, recording noises, for example, from such aircraft as the Convair 880, Convair 990, Falcon Fanjet, Boeing 707 and 727, BAC111, Douglas DC8, and the Lockheed C–5. This type of fly-by testing provides information that enables the designer to predict more accurately flyover noise from initial static ground tests of engines during the early engine development phase. In addition, such measurements for new aircraft can be compared directly with those of current day aircraft. For example, flyover measurements of the C–5 indicated this aircraft to be about the same noise level as the current commercial Boeing 707, even though the C–5 is approximately twice the gross weight with twice the thrust.

General Electric's psychoacoustic noise evaluation program is carried out at the Schenectady Research and Development Center. This program is designed to understand better what types of noises are more annoying to people and

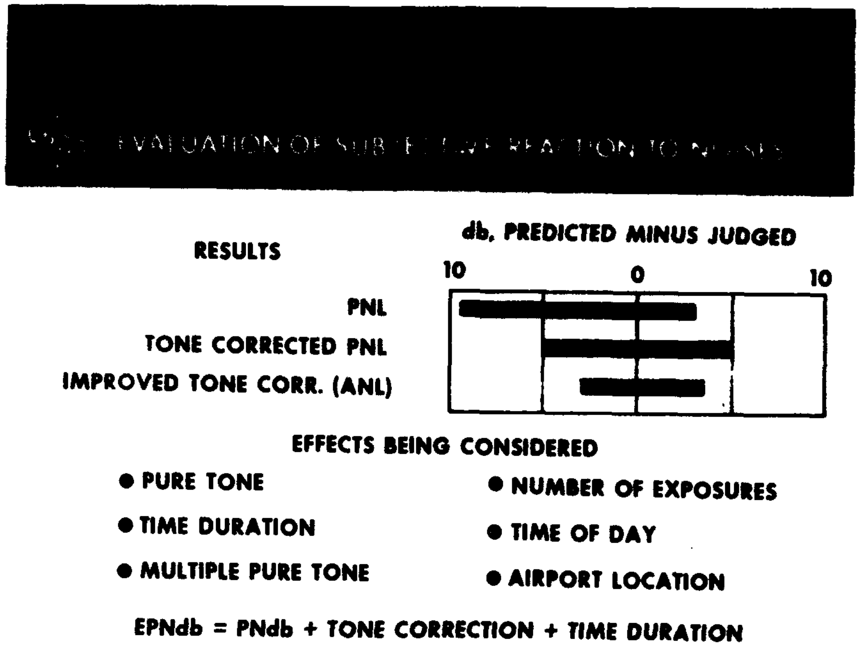


FIGURE 23

subsequently to develop better rating scales ("yardstocks") to be used by the acoustic design engineers. Included as some of the variables in the subjective noises that are evaluated by groups of people are: pure tone content, multiple pure tone content, time duration of noise and number of exposures.

VI. RECOMMENDED ADDITIONAL NOISE REDUCTION RESEARCH AND DEVELOPMENT

A primary objective of the current experimental quiet engine program is the identification of means for significant noise reduction for the fan of the high bypass fanjet engine. This noise reduction, coupled with low core engine jet velocities should provide for a 15 to 20 PNdB reduction in noise as compared to comparable, current commercial engines. At this level, noise from other engine sources such as the compressor and turbine will begin to be heard. Attention will have to be directed to these sources if further overall noise reduction is to be achieved. Two alternative noise reduction approaches might then be pursued—either the reduction of compressor and turbine noise by design (as has been accomplished to a substantial degree with the fan) or the development of acoustic treatment adequate to withstand the hot section environment of compressor and turbine exhausts. In the final analysis, both approaches may be necessary.

Although significant progress has been made in fan noise reduction, much of the progress has been made on the basis of observation and empirical correlation of test results. Additional research and development is needed to determine the cause of noise generation in fans, compressors and turbines, so that further reduction in noise from these components can be achieved. In addition, further work should be done to understand the transmission of noise from the source to the surroundings, and to develop noise control techniques to further reduce the levels transmitted.

Acoustic treatment research and development to date has concentrated on specific application to high bypass ratio fanjet engines such as the CF6 for the DC–10 aircraft, or on investigation of low bypass ratio fanjet engines of today's fleet of DC–8 and 707 aircraft. Generalized investigations of high bypass ratio fanjet engine treatment are required. Improvement and acoustic treatment for the cold section environment of fan and compressor must be obtained, leading to more

effectiveness of treatment in terms of noise reduction per unit weight and per unit cost. A large scale research and development program on acoustic treatment is required, leading also to high temperature treatment for core engine exhausts. Ultimately the fan and core engine jet relative air velocities will establish a noise level that will be difficult to lower. Much additional research and development is required on jet noise, and, in particular, low velocity jet noise such as present in high bypass ratio fanjet engines and forecast for future short takeoff and landing aircraft. Considerably more insight into the exact nature and mechanisms of jet noise generation is required in order to lead to effective means of jet noise control.

At the present time, the main noise measurement scales used are Perceived Noise Decibels and Effective Perceived Noise Decibels, including the effects of noise duration and pure tone noise. There is not adequate agreement among the various agencies and industry as to what a good and sufficient rating scale for aircraft noise is in terms of measuring subjective response. As short takeoff and landing aircraft become operational, improved noise scales will be required to account for effects of metroport background noise and to improve the present scales for application to the widely different noise signatures of these aircraft, which follow from different operational paths, higher installed engine power and variety of noise sources. Much additional work in the subjective noise area must be carried out to provide the engine designers with appropriate "yardsticks" to evaluate their designs and to give guidance for proper land use planning by airport proprietors and municipalities.

Mr. GARRY. All right. We have been producing jet engines in the General Electric Co. since 1942, and we have, in addition to our military engines, if I may abridge the written testimony, also produced commercial engines for the Convair 990 and the Convair 880 transports.

And it was with these engines in the middle and late 1950's that we began our work in jet engine noise. We have in the course of developing this work in engine noise reduction, put in place throughout the country a large number of facilities, and the chart that is on the wall up there shows these facilities (fig. 1).

The facilities include research and development equipment.

Mr. HECHLER. We can't see the chart very well. It is one of these old problems. We can get to the moon very easily, but can't project a chart clearly onto a screen.

Mr. GARRY. We have a chart (fig. 2) of the statement. Beginning up there in the upper left-hand corner; this is a basic research device we have at our Research and Development Center in Schenectady which is involved in the basic understanding of the noise generation and transmission mechanisms.

The facility in the upper right is our Far-Field acoustic test facility in Peebles, Ohio, where we actually measure noise with engines statically mounted in the facility. The picture of the C–5 in the middle is an indication of some of the flyover noise work that we have done at a number of airports.

We have done flyover noise tests on a large number of different kinds of aircraft, with the intent of establishing the relative noise level of different aircraft, the effect of different terrain patterns and what have you.

We also do work in acoustic treatment as shown in the lower left-hand side. At Edwards Air Force Base we also have a noise test facility. With this in mind, and recognizing the work we have done in setting up to do noise reduction work, we recognized as we went into the era of the new jet engines for the DC–10 and other of the so-called trijets and jumbo jets that we would be building engines which had substantially higher thrust levels and, therefore, if nothing was done the noise level would go up.

So, with this in mind, and recognizing this, we began work, actual major work, on reducing the noise of these new engines. The new engines inherently have somewhat lower noise. The earlier engines had high jet noise, and as we increased the bypass ratio, that is the amount of air blown by the fan compared to the basic engine, we began to develop engines in which some 80 percent of the thrust was developed in the fan and only about 20 percent in the main engine as had been in earlier jets.

With this in mind, we actually developed our new commercial jumbo jet engines from the start with the idea of reducing the noise level generated by these engines, even through they were twice as large as the present day engines in thrust. The object was to make a substantial reduction in the noise level of the engine.

Now, to do this, the engines were substantially redesigned and the inlets and exhaust systems were treated with acoustic noise reduction material (figs. 3 and 4). This chart shows the various kinds of design features that are built into the engines which will go into service with this next generation of aircraft.

For example, to reduce the pure tones, the discrete fan whine frequencies, we went to fewer fan blades and eliminated the inlet guide vanes which had caused wakes to go into the fan and had been a noise generating mechanism.

We reduced the number of the rotor blades and increased the number of outlet guide vanes. In other words, we have better than a 2 to 1 ratio of blades to vanes; this had been shown to reduce the perceived noise of the engine. We also spaced the guide vanes away from the rotor, and then we put in acoustic treatment.

Acoustic treatment is very much like ceiling tile in principle, in that there are perforated sheets with acoustically designed core areas that reduce the noise of the engine. So this is a brief background, I would like to play a sound tape which runs about 4 minutes. It shows the—or gives you audible evidence of the work that has been done between the aircraft that are in service today and the aircraft that will enter service, such as the DC–10.

(Sound tape played.)

Mr. GARRY. Thank you very much. This is a brief background of the work that has been done up to date and leads into the discussion of the NASA quiet engine program, which is aimed at further reductions in noise beyond that achieved so far for our jumbo jet aircraft.

General Electric's portion of the NASA experimental quiet engine program is a fan noise reduction research program. I emphasize the fan noise reduction. It is a technology program, not a power plant development per se, but it will obviously have significant implications for further turbofan powerplants. It is anticipated that this program will produce noise reduction 15 to 20 perceived noise decibels below aircraft currently in service.

The program will cover a timespan of 38 months and be completed by the fall of 1972. The first phase of the program is the design phase, and this is nearing completion. This phase is on schedule for completion this month, December 1969. Phase II is optional and involves fabrication and test.

Mr. HECHLER. I don't understand what you mean by optional.

Mr. GARRY. It has not been fully released at this time. In other words, NASA is funding the program in phases, phase 1 program, phase 2 program.

Mr. HECHLER. What is the option, though?

Mr. GARRY. The option is to continue with it, pending acceptance of the designs for fabrication.

Mr. HECHLER. There is some doubt, then?

Mr. GARRY. No. It is just, I mean, the object was to be sure we were on schedule, in both technical and financial areas and then continue on.

Mr. HECHLER. Yes.

Mr. GARRY. The important technical objectives of this program are illustrated in this slide (fig. 5). We are to evaluate both low-speed high-loaded fans, the speed is the speed of the blade at the tip, and high-speed low-loaded fans. The object is to establish the relationship of fan design features on noise generation and then to test these fans with both acoustic treatment and without acoustic treatment, with the goal of relating acoustic theory and actual test data.

Mr. HECHLER. Your chart says "low-speed" and you say "high-speed."

Mr. GARRY. Well, low speed is one group of fans, and this has the tips moving at relatively low speeds but there are actually three fans. Two fans are low speed, with high loading. The third fan is a very high tip speed, and it has low aerodynamic loading per blade.

Next one, slide please (fig. 6).

The object of this; some of our testing has shown that although the lower-speed fans have a lower broad-band noise, that is a general lower noise level, they have very high levels of discrete frequencies and therefore create more human annoyance, and our tests have shown that higher speed fans have a little bit higher base line noise but less of these discrete frequencies and therefore produce less annoying noise.

Now, the object of the program is to evaluate these two types of approach, to see where the proper design balance lies between these two levels (figs. 7, 8, and 9). Specifically, we are to design three fans at the outset, all of which have, when installed on a CF-6 core engine, a bypass ratio of five.

The three fans have no inlet guide vanes (fig. 10). They have the outlet guide vanes spaced two chord widths—that is the width of the blade back downstream from the blade itself, and they have outlet guide vanes. These are the blades that direct the flow from the fan into the exhaust nozzle spacing of two to one, which is twice the chord width back of the fan.

They have relatively low discharge velocities. The fan discharge velocity is about 900 feet per second and the core, the main engine exhaust nozzle, has a velocity of 1,275 feet per second. As I said, we have designed the rig so they can be tested either with sound suppression material or without, to determine how much of the reduction is from the fan design itself, and then how much further reduction we can get with sound suppression material (fig. 11).

Mr. GOLDWATER. Bypass ratio of five; why do you use that significant ratio?

Mr. GARRY. Well, that is typical of these high bypass ratio machines. They range in the five to six and a half regime, and we use this

because it represents a fan size which could have potential application in about a 25,000-pound-thrust engine, and we are using our CF-6 core engine.

This permits us to use an existing engine for testing purposes with the fan on the engine, and that size fan with that engine is approximately five and that is representative of the kinds of engines that are forecast for the future aircraft.

Mr. GOLDWATER. This would be up to 50,000-pound thrust engines?

Mr. GARRY. Yes, it could be. It would be—the present engines range from, I guess about 5½ to 6½, so this is representative, and results in a reasonable cost program using existing equipment to the maximum possible extent. It permits us to concentrate on the noise research rather than on developing new engines for the program.

Mr. GOLDWATER. Could that fact by itself involve any noise factor?

Mr. GARRY. You mean the engines?

Mr. GOLDWATER. Just the ratio.

Mr. GARRY. Yes, it can, but we can treat it analytically to scale it up and down to other bypass ratios.

Specifically, we are to build three fans, the first, two of the fans, as I said, are low tip speed fans. They are about 73 inches in diameter and they are driven by a four-stage turbine. The higher tip speed fan produces about the same amount of airflow in slightly smaller diameter which would be advantageous, assuming the noise levels are comparable, in that it would reduce the size of the nacelle and therefore the drag of the aircraft.

It could also be powered by a smaller number of turbine stages which is a weight advantage and at a comparable weight would allow us to put more sound suppression material in. Of the fans that we are building, there are two 1,100-foot-per-second fans with a design pressure ratio of one and a half. One of the fans has 40 fan blades, rather narrow blades, with a tip shroud for mechanical purposes (fig. 12).

The second fan has 26 blades. You know that the ratio of the vanes to the blades is somewhat greater than 2. And the third fan, the high tip speed fan, has a 1,550-feet-per-second tip speed, a slightly higher pressure ratio, but it has the same number of blades and vanes as fan B, so that a direct comparison can be made between the two, between the low-speed and the high-speed fan.

This gives—yes.

Mr. GOLDWATER. On No. C (see fig. 9) then, the size of your fan is smaller.

Mr. GARRY. Slightly smaller but it has about the same airflow and would produce the same thrust.

Now, in addition to the fan mechanical design, there are aerodynamic features to be tested. We are also going to be testing with different amounts of acoustic material. This is the sound suppression material in various locations and in various amounts in the inlet to the fan and in the exhaust, both the outside shell of the exhaust system and on the inside shell of the exhaust system.

In addition to these three fans, we will test some other ideas in scale model for further reductions in noise. First we will build the scale model, it is approximately half the size of the full-scale fans, and we will test it with fundamentally scale models of the B and C fans.

That is just to give us a model data base point, and then we will try these new ideas that have been predicted to give lower noise, ser-

rated leading edge which breaks up the boundary layer, which improves the flow over the blade and therefore creates less disturbance and potentially less noise.

Also slotted tip blades will be compared to the regular standard blade shapes. We will look at boundary layer bleed control, that is sucking air off the tip of the blade, to reduce the disturbance at the tip of the blade.

Now, from the results of the three basic fans, and from the results of this scale model test data, we will build a fourth fan, which will incorporate the best features resulting from the three full-scale fans and various scale model tests. We will build that in a full-scale fan.

As I said, we are currently in the design phase of the program. We have released material in this phase for the manufacture of some of these parts. We are right now releasing the drawings. At this time we are finishing checking the drawings. We will release the drawings for the various parts this month, so that they can be fabricated into final shape. The program is essentially on schedule at this minute, and a little bit ahead in some instances.

Now, having fabricated the fans we will begin testing in 1970 the various fans and models that we have built. The first part of the test involves the General Electric full-scale compressor test facility in Lynn, Mass. (fig. 13). This is a facility in which the fans will be installed and tested for their aerodynamic performance. That is, the airflow, the performance, the efficiency of the fan, its aerodynamic suitability.

We will also test it with distortion and other factors which have to be considered in the design of real fans. So each of the three fans will be tested in this facility for their fundamental aerodynamic thermodynamic capability.

The fans will then be sent to NASA, and will be acoustically tested at the NASA Acoustic Test Facility at Cleveland, Ohio, so we will first begin by doing aerodynamic tests of the fans, then send the fans to NASA for acoustic tests.

The scale model fans (fig. 14), approximately half scale, with these various serrated edges and what have you, will be tested in this scale model test rig at General Electric's Peebles, Ohio, test facility. This is a scale model rig in which the fan alone, as a component, is tested, driven by a sound-enshrouded gas turbine engine, so that we can measure the actual sound generated by these scale models.

Having completed the acoustic test of the fan by itself, at the NASA laboratory, NASA will send the fans back to General Electric, and we will install these fans on a full-scale core CF-6 engine (fig. 15).

Now, here we begin to take the fan and include it into the total engine. We will have the four-stage turbine driving the low-speed fan, the two-stage turbine driving the high tip speed fan.

We will have representative aircraft inlets, both thick lip and thin lip, as has been projected by the various airplane manufacturers. We install this engine in our facility at the approximate height that such engine would be on the wing of the airplane, and then we measure the noise generated by this full aircraft type system at our acoustic test site.

We run the engine and, therefore, we now have a complete knowledge of the noise level of this fan-type engine in its entirety, the inlet,

the fan, and the turbine and all of the features. We will test the three fans, the two low-speed and one high tip speed fan on this rig.

That is the conclusion of my statement on the quiet engine program. We will, in addition to this, as I mentioned, build a fourth fan which includes the best features that are forthcoming from these three fans. We will test that fan in the aerodynamic test facility and then build it up on the engine and deliver it to NASA for future tests.

This is the presently described scope of the program. And, with your permission, I thought I would talk briefly about two other related fan noise programs that we have under Government sponsorship. The first of these is a program sponsored by the FAA, which is a fan noise prediction program. In this particular program, we are asked to generate mathematical models of various fan systems, and then predict—establish a mathematical computer program which predicts—the noise that would be generated by such a piece of equipment and then compare the mathematical prediction with the actual results obtained on a number of engines, to which the program has been applied.

This particular slide (fig. 16) shows our engine, which is the engine in the Convair 990 airplane. We will also compare the predicted noise with the actual noise measured on a TF–39, the C–5A engine, a business jet engine, our CF–6, and in several versions.

This happens to be the TF–39 scale model engine, so we will get scaling data on engines essentially the same in different sizes, and with different types of fan configurations. From these data that we generate in these tests, we will be able to further improve the mathematical model and, therefore, give the design engineers a better tool with which to predict the noise that would be generated by such machinery during the design process, get a better mathematical or analytical understanding to reduce the trial and error in the development of future engines. We are about two-thirds of the way along into the program which will finish up in July of next year.

This slide (fig. 17) shows the first correlation effort. The dotted line shows the prediction that we made, using our first mathematical model of the noise that would be generated by the TF–39 scale model engine versus the speed or the power output of the engine. That is the dotted line. The red dots show the spread of data actually obtained for this engine, which says that we have been able, with this first cut at a mathematical prediction, to indicate the noise level generated by the fan within about a 5 db spread. Now, what we are trying to do is improve the accuracy of that prediction, and get a better model; we believe as we improve the model, compare it to data, we will get a better understanding of all the parameters involved. We are making significant progress here.

We have one other program, Government-sponsored, by NASA, and this is the prediction of noise in a lift fan which is one type of vertical takeoff, or short vehicle.

Figure 18 is a cross-sectional view of a tip turbine driven lift fan, which is a lifting device. It has a turbine out on the tips of the high flow fan blade. What we have been doing here is testing this type of device, and then varying the design characteristics of it to establish the effect of these changes in design on the noise generated.

For example, the spacing between the blades and the outlet guide vanes was increased (as shown in this view, about 0.25) to a factor

slightly greater than 2—next slide, please—this shows how we do this.

We mount the fan to be measured vertically and then measure at a 250-foot radius the noise generated by the fan with different configurations (fig. 19).

This slide (fig. 20) shows the full fan mounted up at Edwards Air Force Base. It has an engine with acoustically treated inlet to reduce the noise of the engine driving the fan, and then we measure with microphones the actual perceived noise generated by the fan.

We have made one test so far in which we have increased the cord spacing from 0.25 to 2, and as you can see here, we have obtained about a 7 PNdB reduction in noise (fig. 21). We have nine tests beginning in December (NASA-sponsored) (fig. 22) with variations in the geometry and acoustic treatment in this fan.

I won't bother to go through each one of them but essentially it involves changing the blade, the vane ratios and doing other things which we have done with our conventional engines in an effort to reduce the noise. We believe that this will produce about a 14 PNdB reduction in noise which would bring us down to about 110 PNdB, and then further changes in blade numbers, and further acoustic treatment would further reduce the noise.

In addition to these basic engine development kinds of tests and research kinds of tests, we have been working in our research and development laboratory trying to improve our ability to relate measured noise, as we measure it by instruments, to human reaction to the noise. We do this by putting witnesses in a soundproof room and then playing various noise spectrums, different frequency levels, different intensities, different durations to these various witnesses and then try to relate their response to the measurements that we would make for these kinds of noise.

And, as you can see here (fig. 23), beginning with a fairly poor correlation at the top we have begun to gradually improve the prediction from the predicted response to the actual response into a range of somewhat less than 5 PNdB. So, we are making attacks on this noise problem on all fronts, both in terms of better understanding of human response, better understanding of the basic noise-generating mechanisms, and in understanding how the design parameters affect noise.

Mr. GOLDWATER. I wonder if you could be more precise in this. Is this program telling you what the human will tolerate? Or what, in effect, he considers uncomfortable?

Mr. GARRY. What he considers uncomfortable and how to relate, how to get—what are the things that annoy people, and how to measure, how to quantify those annoyances, and then relate them more precisely to the way we measure. We measure with microphones, and they just give us a pure scientific number.

What we are trying to do is to see how these different frequencies, for example a particular frequency, how does that annoy people, so that when we put together a noise spectrum, we can create a less annoying spectrum. And then we are trying to find out how the characteristic of that noise spectrum does bother people, and then get a correlation.

Mr. GOLDWATER. Does he tell you it is annoying him?

Mr. GARRY. Yes, that is right. In other words, from his response and the input as to what annoyed him, what annoyed him most, we can

establish which frequencies, what duration of that frequency, and what have you, relates to human annoyance, and then, as we design engines, we now begin to design such that those frequencies are either not generated or are suppressed.

Mr. GOLDWATER. You take a sample, I assume.

Mr. GARRY. Yes; a very large sample, because human response to noise varies over quite a broad band.

Mr. HECHLER. I would think you would get a tremendous variance.

Mr. GARRY. That is exactly right.

Mr. HECHLER. If you had your people, say, the stolid stable man who had served in the Air Force during the war and was always proud of those planes, if he listens to noise he doesn't hear very much. But the nervous housewife who maybe has been subjected to some tensions of various types, or a man who has a very acute sense of hearing——

Mr. GARRY. Well, in selecting witnesses we try to get the broadest possible type, number of types, so that we relate this to many, many people. It is quite a difficult thing and it takes a lot of witnesses, a lot of work and it just is a work we are doing. NASA, as you know, has requested facilities for similar kinds of testing, and this is a field which I think needs a lot more activity, particularly as we start to try to relate duration as well as tones and intensity.

This puts another dimension on the problem of measuring human annoyance. As you know, on the C-5A, the level is high—as we measure it with instruments the noise level is essentially the same as existing aircraft—the apparent reaction of people to it is that it is quieter, primarily because the noise intensity peak is of shorter duration. It is a very involved psychoacoustic phenomenon we are dealing with, and as you say people vary so we try to get the broadest possible sample, to get us the best possible information on the types of things which cause the greatest average annoyance.

Mr. GOLDWATER. In your testing, did you find that the human is more tolerant perhaps than what has been assumed by alarmed citizens?

Mr. GARRY. I really—I am really not that much of an authority on psychoacoustics. I think we are finding that some of the noise levels, which we measure, are less annoying to people than we would have thought, but that even some lower noise levels are more annoying, depending upon the particular frequency of the noise generated.

Mr. GOLDWATER. Not to diminish its importance, but oftentimes someone attracts attention to a problem that wasn't really a problem until someone mentioned it. One might not have big feet until someone mentioned it and then it becomes a dynamic problem.

Mr. GARRY. We find a relationship between the number of reports of noise annoyance and the time of day, dark and light, whether or not someone expected the noise. A person who looks up and sees the airplane is less annoyed by it than somebody that finds something flying overhead when he wasn't expecting it.

It is a very complex phenomenon. But we are trying to get better understanding, for only through understanding of it can we relate what we do to the reaction of people. And this is a complex field and many people are working on it.

Mr. GOLDWATER. You are trying to establish a standard by which to judge your work?

Mr. GARRY. That is right. We have to design to some standard which is measurable in a quantitative sense and then try to relate that to human reaction. It is quite a difficult thing, but much work is going on, by ourselves and other manufacturers and NASA, and private consulting firms.

I would like to end up here with some basic thoughts on additional R. & D. that might be needed. We believe that a better understanding is needed of the basic noise generating mechanisms within the engine. We have a rudimentary understanding, but we have to do more work in this field to get a more precise understanding, so that we can relate it to design parameters.

The work we are doing for the FAA in predicting techniques is work in that direction, but we are doing some work (and others are doing similar work) in understanding the basic disturbances in flow which create noise. It is a difficult thing to do.

The noise of an engine in today's aircraft, for example, the engines in service, or the TF-39, for example, the total noise energy is something on the order of 31,000 watts, and that engine is capable of producing an energy level of about 25,000 kilowatts.

The CF-6 is about 5,000 watts. So we are talking about 5,000 watts in the 25,000 kilowatt energy field, so we are talking about $\frac{1}{5000}$, roughly, of the total energy developed, so we are looking for the proverbial needle in the haystack. But we do need more research in the noise generating mechanisms.

As we quiet fans, for example, we find noises generated in the machinery becoming predominant; in the TF-39 the fan noise was predominant. As we reduce the fan noise then we begin to reach new thresholds of noise that have to be suppressed, the noise generated in the machinery itself, the noise generated in the jetstream. The original engines had high velocity jetstreams and suppression of that jet noise was somewhat more readily accomplished than today. As the noise goes down in the jetstream we are working with smaller amounts of energy and we need more knowledge of the specifics of the noise-generating mechanism, and new ideas on how to suppress it.

We need more work in acoustic treatment. A lot of work has been done in this area. But as we improve fan noise, my view is we will find ourselves needing acoustic treatment not only in the colder areas of the engine but in the hot areas which means new materials must be developed.

And again, as I mentioned before and discussed the better understanding, more thorough understanding of the psychoacoustics of this noise, how do people react to different noises. This is a field which will require greater and greater attention.

After we reduce the noise as we have for this next generation of aircraft, then the problem, then we are working with a smaller piece of the problem and more work is needed for better understanding.

Thank you, sir.

Mr. HECHLER. Thank you, Mr. Garry. In looking at this from the contractor's side, what could or should NASA be doing in order to place more emphasis on this area?

Mr. GARRY. I know NASA is doing work in the basic generating mechanisms. How are disturbances generated by airfoils, for example. I believe that this work can be extended and must be, as we learn

new things. Right at the minute, the quiet engine program, and the fans that are being developed, I am sure will generate new ideas.

As we test these things, new ideas will grow out of this work, and these have to be looked at very carefully and then further expanded. It is hard to predict precisely what should be done but certainly in the general sense of noise-generating mechanisms, of the interreaction of aerodynamic performance and noise generation, more work has to be done, more work in generating more precise mathematical and analytical understanding of flow disturbances and how to treat them.

In the jet field in particular I believe we need to do more work. We have been concentrating on the fan noise problem, and I believe as we begin to get a better and better handle on that then we will need more work in the jet field.

Mr. HECHLER. Several witnesses have rather perceptively observed, I think, that this was not considered to be a problem several years ago. I think it is a little bit deeper, as Mr. Goldwater mentioned, than just some people saying that there is a problem there before we decided it was a problem.

In our society the economic incentives are all against the person who is on the receiving end of air pollution or water pollution or noise. What gets you started on something like this? Is it simply the dangling of a noise contract by NASA?

Mr. GARRY. No. We have been working with increasing emphasis. As I said, when we began our CF–6 engine, as we began to build bigger engines, we recognized that the public just wouldn't accept higher noise levels as engines become bigger, they just—I mean, they had reached a threshold of noise and we had to not only at least meet that standard with the newer larger engines but we had to make substantial improvement if we were to have a salable product, if we were to meet our responsibility to the public.

And we have actually increased our effort in this area by something like 20 times in the past 5 years. Now, one of the problems is when you begin with a field in which there isn't a great amount of technology, you can only expand that technology at a rate consistent with human imagination and intelligence.

So this is what we have been trying to do. We have been increasing the effort. Noise is one factor in the new engine design, smoke has been another one. We have addressed it, we have recognized it as a public problem, and we have eliminated the smoke trails in our future engines.

So both noise and smoke were considered by the engine manufacturers, by the airlines, as major areas in which work had to be done to maintain public acceptability. And this was a very definite stimulus, as well as NASA's stimulus and other governmental agencies, the FAA and the airlines.

Mr. HECHLER. What about the foreign airplanes that are used by airlines? Would you be able to apply the results of your work to this?

Mr. GARRY. Well, Rolls-Royce in particular has had a very active noise reduction program for many years. Many of the original ideas in the jet-noise suppression were generated in Great Britain, and our competitive intelligence indicates that the Rolls-Royce engines which will go into the Lockheed aircraft have been similarly treated and similarly handled to maintain a similar kind of a noise level.

Mr. HECHLER. To me the most disturbing engine is on the Japanese plane that is used by Piedmont Airlines.

Mr. GARRY. Oh, yes. Well, this is an example of how a very sharp-pitched frequency, although the absolute level of noise may not be beyond a certain threshold, a particular discrete frequency can be very, very annoying.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. I would like to ask you a question. Perhaps this is not an area in which you are involved but one reason, other than perhaps a status symbol, that I enjoy driving in a large automobile is because I can roll up the windows and cut out the noise.

Mr. GARRY. Yes.

Mr. GOLDWATER. Of trucks and buses and what have you. In this world we live in, we have an environment full of noise. Of course the jet engines are only a very small part of it. Has your company at all tried to, or thought about using the technology that they are developing to suppress engines noise, in your testing and evaluation of the tolerance of the human being, to contribute to the overall environment of our lives in general? Machinery, buses, working conditions, office conditions? Maybe that is completely foreign——

Mr. GARRY. I can't give you a specific example, but our research and development laboratory at Schenectady is a focal point for technology within the General Electric Co. The folks up there are very much aware of what we are doing, they are doing a lot of work for us, particularly in the realm of basic research in the mathematics and the fundamental physical nature of noise generation, and this subjective noise work is also being done up there, in fact by a man who is an authority on radio noise, tone quality, and what have you, so some of the work is undoubtedly moving into other elements of the company.

Mr. GOLDWATER. Is this under the general contract that you have with NASA?

Mr. GARRY. No, it is not. It is a natural spillover since the people who are involved working with us on this are in direct contact with other portions of the General Electric Co.

Mr. GOLDWATER. From a profit standpoint this might be a lucrative field of endeavor. I don't have too many other questions. I just wondered, are there noise characteristics that are inherent in certain types of material; for instance, I think you used some sort of titanium; don't you?

Mr. GARRY. Yes.

Mr. GOLDWATER. Is there any noise inherent in that material itself?

Mr. GARRY. Well, we don't really have any good quantitative correlating data. However, the fan, one of the fans that I mentioned up there, the fan B, which has wide blades, one of the objectives of making the blades that wide was the possibility of using epoxy-graphite composite material. This fan would be directly amenable to manufacturing of epoxy-graphite and this would be a nonmetallic. We would like, sometime, to try such a nonmetallic in the hope that maybe it produces lower noise.

Mr. GOLDWATER. I think there is so much research being done in this right now; isn't there?

Mr. GARRY. Yes: there is.

Mr. GOLDWATER. Is it being done over in England?

Mr. GARRY. The British have done very much work in the field of composites. We are also building blades of composite material and aircraft structures are being built of composites. So this probably is a major new industry in the next few years.

Mr. GOLDWATER. As I understand it, as far as the jetstream is concerned there is not too much you can really do about that. Is that what you found?

Mr. GARRY. Well, we have reduced it to the point where it is not—it does not establish the maximum noise annoyance level. We are moving down to the point as we reduce fan noise, where it may very well become the noise—a new threshold of noise, and we are working in this field very extensively now.

Mr. HECHLER. I don't quite understand what you last said, when you said you are working in this field. Does that mean you are simply trying to establish where the sound comes from or are you trying to do something about it?

Mr. GARRY. We are doing both. We are doing basic work in trying to establish just how the noise is generated by jet fields, and we are also working on a wide variety of ideas on suppressors which would reduce that noise.

Mr. HECHLER. You are convinced, though, that that is not the real source?

Mr. GARRY. Not at this minute with turbofan engines, but it could be, let's say, as a result of making further reductions in fan noise.

Mr. HECHLER. In other words, that other noise will come to the surface?

Mr. GARRY. That is right. The one thing we find is that the more we do, the more we reduce one source of noise to a minimum, we find that it was perhaps blanketing another source, then we have to attack that source, and so on. So it is a never-ending quest.

Mr. HECHLER. You can't win.

Excuse me, Mr. Goldwater.

Mr. GOLDWATER. Are you finding also that in reducing noise in certain areas, you are having to pay a big price to do this as far as—the ratio of power outputs, say, of weight or——

Mr. GARRY. Well, aerodynamic performance has been penalized less than weight. As we space the fan away from the outlet guide vanes, the engine length becomes longer. Length is weight. As we put acoustic suppression material in, this is weight.

The advantage, as I mentioned, of a higher tip speed fan, if the noise is comparable, would be that it would compensate to some degree for the added weight of the length, because it is a smaller diameter, and so forth.

So the object here is not only to try to reduce noise, but to also try to maintain an economically viable system. We can't penalize aerodynamic performance to the point where the aircraft becomes not flightworthy or can't make its intended range.

Mr. GOLDWATER. One last question. Is there one particular area that creates more noise than any other area? I mean, at least right now, is it in your studies?

Mr. GARRY. In the turbojet, correction, the turbofan aircraft, such as the air bus, certainly the fan is the major source of annoyance.

Mr. GOLDWATER. More so than the exhaust?

Mr. GARRY. Yes. That is why the TF–39 sounds less noisy, although the absolute noise level is roughly comparable to today's aircraft. As the plane flies by you hear the fan noise, then a sharp drop, as you go out of the field of the fan noise and into the jet noise, which is very low.

Mr. GOLDWATER. Thank you very much.

Mr. HECHLER. Thank you, Mr. Goldwater. Can you give us an assessment, at least of V/STOL engines and what our progress has been in that area?

Mr. GARRY. Well, I can only talk from my own experience. We build two types of V/STOL engines, basically turbo—I won't say that. We have built these tip turbine fan, lift fan V/STOL-type aircraft which I showed, and we are working in the noise reduction field in that.

Helicopters are another type of VTOL aircraft; we build turboshaft engines for these. In the case of helicopters we have turboshaft engines with a power turbine at very low exhaust velocities, very low noise, and you can suppress the inlet noise by inlet duct treatment on such aircraft.

We have had less experience with other kinds of VTOL aircraft, direct jet lift, which are quite noisy, and tilt-wing aircraft which are turboprop and a fairly low-noise aircraft.

Just offhand, I would say that we can reduce the noise level of the engines, or turboprop, V/STOL, and turbo-tip fan or lift fan kinds of aircraft. In the case of blown-flap aircraft, which is a deflected jet aircraft, I believe the same noise reduction techniques that are being applied to the air bus engines are applicable in this field.

Mr. HECHLER. In this whole argument as to which type of V/STOL or STOL we ought to go ahead with, I wondered whether the noise factor played an important part and perhaps additional work by you might be able to remove one of the inhibiting factors in the further development toward a prototype.

Mr. GARRY. Certainly the emphasis, the major emphasis today, has been on the more conventional aircraft. There is an increasing emphasis being placed by NASA and by the airlines and by the airplane industry in noise reduction for V/STOL types.

Mr. HECHLER. Should there be more by NASA?

Mr. GARRY. I would think that an increasing effort here would be very worth while.

Mr. HECHLER. Mr. Garry, this is most interesting. We have a number of other questions we would like to sul it to you in writing because we have another very important witness this morning. We thank you for appearing before the committee this morning.

I appreciate very much your coming, and you will be receiving several other questions from us to complete the hearing. Meanwhile if you have any further data along the lines of the discussion, or questions that we asked this morning, that you care to submit for the record, we will include it in the record.

Thank you very much, sir.

Mr. GARRY. Thank you, Mr. Chairman.

(The information referred to follows:)

RESPONSE BY FRED W. GARRY, VICE PRESIDENT AND GENERAL MANAGER, AIRCRAFT ENGINE TECHNICAL DIVISION, GENERAL ELECTRIC CO., TO QUESTIONS OF THE SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY

1. Question. (a) From your work so far, does the noise reduction goals of 15 to 20 PNdB appear to be attainable without significant loss of efficiency or an added cost burden to the user?

(b) What is your time forecast and cost estimate as to when these features can be incorporated into new aircraft engine production?

(c) Do the noise reduction figures include the jet noise output or only the fan and compressor noise?

(d) Since fan and compressor noises only alleviate the situation on approach do you feel that the reduction will be worthwhile for a major user?

Answers. (*a*) Based upon the results of research and development work done to date related to noise reduction design concepts, including the use of acoustic treatment, the goal of 15 to 20 PNdB reduction appears feasible. (It is appropos to point out that a reduction of 20 PNdB is approximately equivalent to a 99% reduction in noise energy.) The design concepts that reduce noise most generally result in weight additions to the propulsion system, and therefore in turn result in added cost burden to the user.

(*b*) Some of the features are currently being included in new aircraft production, at least to a degree. It is further anticipated that other of these features, as they are proven, will be incorporated as time goes on, possibly as production modifications or as design features at the inception of new propulsion systems. Certification of new propulsion systems from the time of initial design requires approximately 100 to 250 million dollars and around 4 to 5 years time period. Modification of existing systems such that airline reliability can be assured range from one year to three years. With these facts in mind the advanced ideas emanating from the Quiet Engine Program could be introduced into service perhaps for 1972 for military proved concept through 1976 for the concept developed late in the program or which require development of totally new systems.

(*c*) The noise reduction figures include the jet noise output. For the Experimental Quiet Engines, requirements were established for the jet velocities to minimize the noise emanating from these sources.

(*d*) Providing due consideration is given to minimizing the jet noise sources, as in the design concept for the Experimental Quiet Engines, fan and compressor noise reductions should not only alleviate the situation at approach but also at the side line and beneath the aircraft after takeoff. In particular, this appears to be the case for propulsion systems with bypass ratios of about 5 or greater.

2. On page 6 of your statement you indicate that the TF39/CF6 engine core will be used.

(a) Question. Have you begun to investigate the prospects of retrofit of existing aircraft to determine the costs and extent of retrofit required?

Answer. The General Electric Company has not done any studies in this area. NASA has conducted a study program through a contract with the McDonnell Douglas Corporation to determine the costs and retrofit extent in a DC8 aircraft (Contract NAS 3-11151).

(b) Question. Does the design data developed apply to other engines and will you be able to forecast results if the same technology is supplied to an engine manufactured by others?

Answer. Yes. The Quiet Engine Program is directed toward developing this design technology for lower noise aircraft engines and demonstrating it on two different designs of high bypass fans.

(c) Question. What aircraft now in widespread use would be affected?

Answer. From a technical point of view the Quiet Engine Program features are applicable. From an economic point of view the question of essentially reengining the fleet is a matter of timing and cost that would require airline/airframer input.

3. Question. In view of the subjective nature of noise effects on humans, do you suggest that the engine finally delivered to NASA be flight tested and the results compared with the standard engine?

Answer. The Quiet Engine delivered to NASA is expected to be possibly 15–20 PNdB quieter than current airline engines. Experience with ground static testing of the CF6 engine has shown that the subjective response confirms that this engine is much quieter than current engines. The CF6 measures 10 PNdB quieter.

Furthermore, the Quiet Engine has been designed so that the dominant frequency of the fan is well below that of the current engines; therefore, its annoyance will be less. A preliminary evaluation of subjective response to the effectiveness of the noise reduction achieved in the Quiet Engine can be obtained by ground static tests, just by running the Quiet Engine and then a current engine, and obtaining listener response. Further substantiation could result from a flight test program to determine subjective responses.

4. Question. Although you suggest additional work on noise measurements and instrumentation, you do not specifically suggest work on jet noise reduction. How would you attack this problem? What do you forecast as attainable goals within your fan noise time scale?

Answer. Jet noise reduction of a significant magnitude has been achieved by the use of high bypass ratios in engines such as the TF39 and CF6. This reduces jet velocity and increases airflow to obtain required thrust. At velocities of interest, acoustic power varies with the eighth power of velocity and the first power of mass flow. At the levels of jet velocities that will exist in these engines, experience shows that the types of suppressors used on today's turbojet engines (CJ805–3, JT4D) are not effective.

Under the Quiet Engine Program we will examine different methods of exhausting the fan and core engine flows to see if there is an effect on jet noise. Preliminary data on a lower bypass ratio, high jet velocity military engine showed that mixing the fan and core engine flows reduced the noise by about 1–2 PNdB. Further experimentation and research in low velocity jet noise and techniques for its suppression are required. Without this type of program it is difficult to forecast attainable goals in any time period.

5. In previous testimony it has been suggested that major emphasis on aircraft noise reductions did not occur until the past 4 or 5 years. In this respect, you state that you have been working on engine noise problems for a number of years.

Question. How would you compare what you are doing today with your work of some years ago?

Answer. We started working on engine noise problems about 1955 in order to reduce the jet noise on our CJ805–3 turbojet engine, which powers the Convair 880 jet transport. This work culminated in a suppressor which reduced jet noise by about 5 PNdB at takeoff. Effort continued at this level until 1966, when we entered the competition for the DC10. The larger thrust required, combined with the high bypass technology, indicated that there would not be an escalation of noise at takeoff, but that at approach the fan whine would be significantly higher. Therefore we expanded our efforts in the design and development of a low noise, high bypass fan and acoustic treatment materials, in order to achieve a sizable reduction in noise. Our efforts have more than quadrupled to accomplish this. The addition of the Quiet Engine Program will further increase our efforts in 1970 in order to attain even greater reduction in engine noise.

6. Military and civilian aircraft engine have had a great deal of commonality in the past.

Question. Would you agree with this?

Answer. With few exceptions, commercial jet engines have been modifications from military engines. This commonality has been mutually advantageous. Technology from the military engines has provided the base, and the long hours of experience that result from commercial service have contributed extensively to durability and combat reliability of the military engines and the subsequent improved models.

Question. Have noise reduction considerations been design criteria in the development and production of engines for military aircraft?

Answer. There have been no noise requirements for our military engines. Military engines must represent minimum compromises if the desired edge in performance is to be achieved consistent with our national security posture. Noise reduction features and treatment represent compromises that only the military can assess.

Question. To what extent do the C–5A engine and its commercial version, the CF6, differ?

Answer. In looking at the differences between the CF6 and the TF39, it must be remembered that the CF6 has been optimized for the DC10 commercial mission profile which includes higher cruise speeds and shorter flights than the C5A. Also, the CF6 program go-ahead was in April 1968 which allowed the CF6 to benefit from the TF39 development experience and to take advantage of the latest state-of-the-art in engine design.

The most significant differences between the TF39 and the CF6 include:

(1) Fan design for low noise features and lower bypass ratio than the TF39 to be compatible with the DC10 flight regime.

(2) Combustor design to eliminate visible smoke.

(3) Low pressure turbine modified to be compatible with the smaller CF6 fan described above in Item 1.

(4) Accessory drive gearbox and engine accessories were relocated to the outside of the fan case.

(5) The thrust reverser was changed from the TF39 to be compatible with the DC10 airframe.

(6) A thrust spoiler for the core engine was added to meet the reverse thrust requirements for the DC10. A thrust spoiler is not required on the C5A.

Question. Would noise reduction modifications impair the performance of the C-5A engine?

Answer. The effect of noise reduction modifications on performance of the TF39 would depend on what noise criteria was established and how much the engine was modified. We would expect that there would be some loss in thrust, increase in specific fuel consumption, and an increase in installed weight if modifications were made to the existing engine. If the engine was initially designed to meet the same noise requirement, the penalty would be less. It would take a significant study to generate specific numbers on the effect of noise reduction modifications on the TF39 engine, and the effect of these modifications on the C5A weapons system capabilities.

Question. Would you judge that the state of development of STOL and V/STOL engines is such as to permit us to move STOL and V/STOL prototypes?

Answer. STOL and V/STOL aircraft prototypes could be built using engines currently in advanced stages of development. Such prototypes would not yet show the levels of profitability and minimum noise levels attainable with new advanced technology engine types.

However, the technology needed for such engines is already demonstrated in principle and well understood. They could therefore be developed concurrently with early aircraft prototypes leading to commercial operations beginning in 1975 for STOL and 1976 to 1980 for V/STOL. This will require a decision to go ahead with engine development no later than 1971.

Question. On page 16 you refer to the value of flyover testing in design. Are there any problems with this type of testing?

Answer. Care must be taken to conduct these tests in areas where the terrain does not significantly distort the noise measurements. This means that flights over deep grass or extensive concrete pavement must be avoided, since the former absorbs a great deal of the acoustic energy and the latter reflects it almost completely.

Secondly, weather conditions must be nearly perfect; that is: no temperature inversions, which tend to focus the noise at specific locations; wind velocities below ten knots, so that focusing and scattering are minimized.

Third, aircraft position, attitude, and velocity must be known at the time measurements are taken. This is accomplished by cockpit instrumentation and the use of either synchronized cameras or radar tracking.

When the above conditions are met, flight tests do provide valuable, valid data on acoustic performance which, when compared with ground static data and flight predictions, can yield more precise correlations between ground and flight performance and consequent effects on the design.

Question. Do you think your research efforts are being hampered by the lack of the Noise Reduction Laboratory proposed by NASA for the Langley Research Center?

Answer. The Noise Reduction Laboratory proposed by NASA for the Langley Research Center will allow for more fundamental studies to be conducted which could yield noise reductions beyond those sought in the Quiet Engine Program. With such a facility, more attention could be paid to the details of noise generation and propagation mechanisms and noise attenuation techniques that are more

efficient than those planned for the new wide body aircraft and for the Quiet Engine.

Question. What is the status of work in investigation and reduction of compressor and turbine noise? How important is this line of research relative to that now going on in fan noise reduction?

Answer. To this point in time, fan noise has been the dominant noise source from the propulsion system rotating machinery. With progress in reducing the fan noise source, experimental results indicate that turbine noise may well be the next dominant source. Analytical investigations have been initiated (as they were with fan noise) to better understand this source. In addition, experiments have been planned, some of which involve acoustic treatment behind the turbine, to reduce turbine noise. Future noise reduction programs should include more effort related to turbine noise reduction.

Question. You presented off-the-cuff ratios in watts showing the amount of engine power converted into sound energy. Could you supply this data on a series of representative engines including those you discussed?

Answer. The following table provides the requested data.

Engine	SLS thrust, pounds	Acoustic energy, kilowatts	Total energy, kilowatts	Acoustic energy in percentage of total energy, kilowatts
CF6 turbofan	40,000	5.0	24,500	.02
CJ805-3 turbojet	11,000	63.0	13,500	.468
CJ805-23 turbofan	15,000	10.0	11,800	.084
TF39 turbofan	41,000	31.0	25,000	.124
CF700 turbofan	4,100	2.6	2,900	.088

Mr. HECHLER. Our next witness this morning will be Gen. Clifton F. von Kann.

STATEMENT OF GEN. CLIFTON F. VON KANN, VICE PRESIDENT, OPERATIONS AND ENGINEERING, AIR TRANSPORT ASSOCIATION OF AMERICA

General VON KANN. Good morning, Mr. Chairman.

Mr. HECHLER. Good morning, sir. Good to have you back before the committee.

General VON KANN. Nice to be here again, sir. I am accompanied this morning by my colleague, Michael J. Strok, who works in my department and interests himself in this area considerably.

Mr. HECHLER. Does he have a title?

General VON KANN. What is your correct title, Mike?

Mr. STROK. Director of program planning.

General VON KANN. Director of program planning in the operations and engineering department of the Air Transport Association.

Mr. HECHLER. You may proceed.

General VON KANN. Thank you, sir.

Mr. Chairman, members of the committee, my name is Clifton F. von Kann. I am vice president, operations and engineering, of the Air Transport Association of America, the trade and service organization representing virtually all the scheduled, certificated airlines of the United States. It is a pleasure to appear again before your subcommittee.

You will recall that in our appearance last fall several airline experts gave their views on the important subject at hand. Were these gentlemen to reappear here now, their testimony would probably not change significantly from that given last year.

Using these views as a platform, I will attempt today to discuss the air transport system in a general way and to indicate the types of research and development which I think will be most important to our continued progress during the coming decade.

First, a few thoughts on where we stand today.

As you know, jet engine technology brought a transportation revolution to our country about 10 years ago. Today most of our public intercity travel is performed by air. In 1958 the airlines accounted for 39.3 percent of the passenger miles performed in public intercity transportation. In 1968 the airlines' share was 72.5 percent. In intercity travel of 200 miles or less, the private automobile is still the most popular mode of transportation, but even here the airlines have made inroads.

Now, this growth in air transport has been spearheaded by the aircraft and engines. Fortunately, during the 1960's the old airport and air traffic control systems were able to support the increased traffic without excessive strain. Now, however, the strain has become excessive; and today we have a crisis in airport and air traffic control capacity—especially in our higher density areas.

Let me describe our problems in some detail, for an understanding of these problems is needed if future needs for R. & D. are to be assessed intelligently.

We have three major areas of concern in the U.S. air transport system which bear on R. & D. needs. These are:

First, operational facilities, by which I mean airports and airways.

Second, connecting facilities (intermodal and intramodal.)

Third, our effect on the environment and the quality of life.

With respect to operational facilities the problem is complicated by differing organizations. The Federal Government is responsible for the airways. On the other hand, airports are built and operated by a variety of local jurisdictions—sometimes directly and sometimes through authorities deriving their charter from one or more of the political jurisdictions involved.

This results in different motivations, different pressures, different ground rules. It does not make for expeditious action that can recognize and satisfy air transport requirements. Hopefully, the new Department of Transportation in the Federal Government can help to find solutions. In any event, these are realities which bear on R. & D. efforts.

Mr. HECHLER. Excuse me. Are you going to give any suggestion or just throw the ball up in the air?

General VON KANN. I think on that one, sir, I would have to throw the ball up in the air. I could discuss it. I think there is some thought being given in the Federal Government to use the State jurisdictions to a greater extent, pulling power up from local jurisdictions. This has some good and bad things about it.

I think it is too early in the game for me to say what the right course is.

Mr. HECHLER. It is real fine when you are in the middle of a State, but when you get over to the State border, then there is a problem.

General VON KANN. This is true. And I think the problem is recognized, but I think it is pretty early in the game to suggest the courses of solutions. This may take some special R. & D. of its own.

Mr. HECHLER. Well, I would only suggest that it may be later than you think.

General VON KANN. Yes, sir; agreed.

Mr. HECHLER. You may proceed, sir.

General VON KANN. The problems of connecting facilities are of another type. Let us first consider intermodal connections, that is, transfers between aircraft and other transportation modes—taxi, bus, limousine, private auto, train, or subway.

With few exceptions, airport access systems do not support the peak needs for intermodal connections, and this can make the rush hour at our larger hub airports a nightmare for the passengers. Since the other travel modes must be provided by nonaviation systems, and since these must satisfy nonaviation needs, the problems of keeping them in balance with the requirements of air transport are staggering.

But even intramodal connections between aircraft pose formidable problems for the passengers. Despite the fact that the airlines spend a great deal of time and effort working out convenient connecting schedules, these schedules can never be ideal for everyone. Where the system runs into serious delays—as it often does today—interconnecting passengers may fail to make their connections, notwithstanding the most energetic efforts by the airlines to protect their customers.

Even if there were no problems with connecting schedules, with the growth in air traffic, in the size of airports, and in distances between different air carrier gates—this may amount to several miles at the new Dallas-Fort Worth Airport—it is becoming more time consuming and difficult for passengers to make interline transfers.

Even helicopter and STOL connections between downtown and the airport have their problems. These are necessarily high-cost air operations, and the passenger often has to use another transport mode between the helicopter (or STOL) and the airliner.

Turning to the third problem area, our effect on the environment and the quality of life, this is the most recent major development, perhaps the most urgent, and surely the most complex.

The complexity is due to changing social attitudes in the United States. For most of the last 100 years we were a Nation dedicated to industrial and economic growth through technological progress. To a great extent people had to get out of the way of technology, which was not unreasonable because we had plenty of room. If anyone was unhappy about the noise of trains, trucks, or boat whistles he could go elsewhere.

But now our urban areas and many of our suburbs are crowded. Our people are having to learn to live under more crowded conditions, to wait in line, to make accommodations to one another. They are having to learn amenities which a few generations ago seemed less important. Meanwhile our political leaders and the judicial system are insisting that the environmental needs of individuals be given greater consideration and that the quality of their life be protected.

As you know, the airlines are under great pressure to reduce jet aircraft noise—even though there is no easy or immediate solution. Noise restrictions at various airports have already reduced available capacity of these airports. Now there is increasing agitation for the airlines to eliminate the visible smoke exhaust from jet engines, even

though this smoke is not really a pollutant and has some safety benefits in that it increases aircraft conspicuity.

Let me note for the record, however, that the airlines foresaw this problem. The resulting programs of the airlines and engine manufacturers have already arrested the increase in engine smoke; and it will not be too many years before all airline engines are virtually smokeless.

I will add for the record a copy of a statement I made last week at the Chicago Press Club where I held a press conference on the airlines' voluntary program to reduce smoke emissions from our aircraft in support of this statement.

(The document follows:)

STATEMENT OF GENERAL CLIFTON F. VON KANN, VICE PRESIDENT—OPERATIONS AND ENGINEERING, AIR TRANSPORT ASSOCIATION, REGARDING VOLUNTARY INSTALLATION OF IMPROVED FUEL COMBUSTORS ON JET AIRCRAFT, DECEMBER 4, 1969, CHICAGO PRESS CLUB, CHICAGO, ILL.

These are the main points in the airlines' program to reduce air pollution:

1. Airline aircraft emit only a negligible percentage (about 1%) of the man-made pollutants placed into the atmosphere from all sources. This creates primarily an esthetic, rather than a health problem.

2. Despite the fact that 99 per cent of all pollutants come from non-aviation sources, a voluntary industry program to eliminate particulate emissions from the prime airborne source—JT8D engine—has been underway for more than four years. This program has been supported entirely by the engine manufacturer and the airlines using that engine. The program has produced new combustion chambers, or burner cans as they are commonly called, which are new being operationally evaluated by four of the larger ATA member airlines.

3. The time required to gather the required operating experience with modifications to the hot section of the JT8D is about two and a half years, of which roughly one year has already been completed. This means that the service evaluation of the new burner cans for the JT8D should be completed by late 1970.

4. If the results of the current operational evaluation are satisfactory, it is the intention of the airlines to incorporate the revised burner cans into the JT8D engines as rapidly as overhaul schedules permit.

5. As of last week, the operational evaluation by four ATA member airlines has now brought some of the new combustion chambers beyond the 3000 hour mark. However, there has been relatively little operation above the lower engine power rating.

The information I will supply on behalf of the airlines will show that voluntary efforts, which began quite some time ago on the initiative of the industry, are producing a reduction of visible contaminants which will see their virtual elimination at the earliest practical time.

AIRLINE CONCERN WITH AIR POLLUTION

The airlines fully appreciate, and are deeply concerned generally with, the effects of air pollution on our operating environment. A major industry concern with air pollution is in its effect on visibility. In most instances pollution of the atmosphere is synonymous with reduced visibility. This is especially true of the heavy suspension of contaminants in the form of particulate matter and hydrocarbons.

This does not mean that the presence of air contamination renders airline flight operations unsafe. Airline aircraft and flight personnel are especially equipped for instrument operations under conditions of reduced visibility caused either by weather or man-made atmospheric pollution. Moreover, minimum visibility conditions for aviation operations are carefully established by the air-

lines, and by the Federal Aviation Administration, to insure that landings and takeoffs are made only under suitable conditions.

CONTRIBUTION OF PRESENT AIRCRAFT EMISSIONS TO THE TOTAL ATMOSPHERIC POLLUTION IS SMALL

As determined by several local and Federal sponsored studies the two principal targets of pollution control efforts are sulphur compounds and carbon monoxide. Jet engine produce no sulphur compounds and very little carbon monoxide. On the other hand, these studies show that automobile exhaust, which in some locations constitute as high as 90 to 98 percent of all the contaminants placed in the air by man, include a high percentage of both sulphur compounds and carbon monoxide.

Jet aircraft do produce relatively infinite small amounts of hydrocarbon and other organic gases, aerosols (smoke is an aerosol), oxides of nitrogen and carbon monoxide. The percentage of contaminants placed in the atmosphere by jet aircraft engines, as related to the total atmospheric pollution placed in the atmosphere by man, is on the order of slightly more than 1 per cent.

As the Secretary of Health, Education and Welfare in his report to the Congress in December 1968 indicates, "The present contribution of aircraft emissions to the total atmospheric pollution burden of the community is considered small." This is similar to the conclusion of the U.S. Public Health Service Study undertaken at Kennedy International Airport in the fall of 1964 covering pollutants attributable to operations at airports.

While these public reports show that commercial jet aircraft are contributing only very limited amounts to the overall pollution level, even in these areas of high traffic density, it is the objective of the aerospace industry's program to reduce the level of smoke emission to the absolute minimum. As a matter of fact, since 1958 engineering groups from the airlines, engine manufacturers, and fuel industry have been actively and voluntarily pursuing the problems of and solutions to exhaust smoke from jet aircraft. Many studies have been conducted to ascertain mechanisms of smoke formation in turbine engine combustion systems.

WHAT IS THE AVIATION INDUSTRY DOING?

Future Aircraft

As a result of study, testing, experimentation and evaluation to date, the future holds great promise for decided improvements in the next generation of aircraft such as the Boeing 747, the Lockheed 1011, and the DC-10. The newer engines which were designed and developed by engine manufacturers for these aircraft have combustion systems of more advanced design. The technical experience gained in the past as to the design feature which reduced smoke were incorporated in the engines. The elimination of exhaust smoke has become a routine development goal and is included in our technical specifications. as a result the airlines will be operating these new airplanes with engines which are essentially smokeless.

Today's Jet Aircraft

Research by engine manufacturers is currently probing smoke reduction possibilities for several of the engines which now power the jet transports flying today.

Principal attention has been focused on the smoke plume emitted by the JT8D jet aircraft engine. This engine powers the Boeing 727, the Boeing 737, and the DC-9. The manufacturer of this engine, Pratt & Whitney, has been attacking the smoke problem for well over 4 years. Primary emphasis has been on eliminating the particulate emissions which cause the smoke from jet engines. The main offender in unburned tiny carbon particles caused by localized incomplete combustion in the burner cans.

The burner can is the heart of the jet engine. It is where fuel is mixed with compressed air and transformed by ignition into burned gas to form the propulsive thrust of the engine. Pinpointing the localized rich pockets in the burner cans was the first step toward smoke reduction. Once indentified and adjusted, over 500 test rigs were run-in to confirm results. Then, more than 200 full-scale

engines were run with different burner can configurations before a suitable design was selected for FAA certification.

FAA certification followed a 200 hour testing program by the manufacturer. A little over a year ago 37 engine sets of these newly fabricated and improved burner cans were delivered to 4 of the larger member airlines of the ATA for in-service operational evaluation on 727, 737, and DC-9 powered aircraft. The prime purpose was to determine how these new cans would operate during prolonged periods in the airline environment and to find the service life of these components under day-to-day airline operations.

A run out of at least 5,000 hours on all engines furnished the carriers will take up to 2½ years. At present, ATA participating airlines have accumulated more than 3,000 hours on one engine set of cans being evaluated and as low as 200 hours on another. Most of this operation has been at the lower engine power rating In short the airlines are more than half way through the operational evaluation which should be completed in the fall of 1970.

It should be noted that this is not an excessively long period of evaluation. Unless the service life of these new cans is firmly determined when they are introduced into general airline service, engine life could be drastically reduced which would disrupt maintenance cycles and present the industry with virtually impossible problems in maintenance scheduling. Further, a short period of evaluation would fail to give the manufacturer the information he will require to eliminate the "bugs" from the new type burner cans.

With respect to the jet engines which power aircraft such as the DC-8, the 707, and Convair 880 (in other words, the JT3 and GE C805 engines), as soon as the manufacturers of these engines can provide the airlines FAA certificated engine "fixes", operational evaluation of these items on airline aircraft will begin.

SUMMARY

The airlines' views can be summarized as follows:

1. New generations of airplanes such as B-747, DC-10 and Lockheed 1011 will be delivered with essentially smoke-free engines by the mid-1970's. They will amount to over 10 per cent of the U.S. airline fleet.

2. Regarding the JT8D engine, over a year ago the airlines voluntarily started an in-service evaluation of new burner cans provided by the manufacturer. Until at least 5,000 hours of service evaluation on each of the 37 engines is completed, the airlines determine their specific program of retrofitting this type of burner can in their fleets.

3. When the manufacturers of such engines as JT3 and the GE CJ805 have completed an appropriate smoke emission "fix" on their engines, the airlines will undoubtedly evaluate them operationally as well.

4. While it is impossible to make firm forecasts at this point in time, I believe it is safe to say that these actions will result in the majority of airline engines being smokeless by the mid-seventies.

Mr. HECHLER. Are you seriously saying that there is no fallout or no pollutant other than what is——

General VON KANN. As far as toxic pollutant, all the studies that have been made on that matter indicate that those are negligible quantities. Usually something under 1 percent, or in the vicinity of 1 percent of all the pollutants in the atmosphere. Now, on the other hand, the nontoxic pollutants, which are largely the smoke, the soot, the water, oxygen, substances like that, are about 99 percent of what comes out of the tail of these jets.

Mr. HECHLER. I see. Then you ought to add the adjective "toxic," perhaps, to your statement. You said this smoke is not really a pollutant.

General VON KANN. Yes, that might be so, although the HEW themselves classify this not as a pollution problem but as a problem of esthetics. But depending on whether or not you associate the word "pollution" with toxicity, some modification of this nature would be in order.

Well, anyway, I will submit this briefing, sir, which indicates what we are trying to do about that.

Mr. HECHLER. All right, that may be included.

General VON KANN. Would you like to have that up at your desk?

Mr. HECHLER. That would be helpful, yes.

General VON KANN. Concern for the environment is also affecting airport construction. It is becoming more and more difficult to obtain approval of a new airport site—or even to improve and expand existing airports. The benefits which an airport brings to a community tend to be forgotten in the strong concern for environmental integrity.

Now I turn to the prospects for the coming decade, the decade of the 1970's. Our efforts to solve the above problems will dominate the greater part of the next decade. I believe that the extent of our success or failure will be determined largely by the extent to which new technology is utilized in the civil air transport system of 1980. We must therefore do some forecasting and attempt to assess the most serious difficulties which the coming decade will bring.

With respect to operational facilities, I believe we will achieve adequate or near-adequate airway capacity by the late 1970's. Federal user charge legislation which will provide the necessary funds is all but certain to be enacted.

The technology for the necessary automation of the air traffic control system is available or can be made available in the desired time frame. The necessary authority exists in the Federal Aviation Administration. Moreover, the problem has been studied in some depth on several occasions, the most recent effort being the work of the Department of Transportation ATC Advisory Committee, chaired by Dr. Ben Alexander. The airline input to this study is contained in the report of a special airline study group called the Air Transport Association ATC systems planning group.

And I also offer a copy of that report for the record.

(The document follows:)

AIR TRANSPORT ASSOCIATION OF AMERICA
1000 Connecticut Avenue N.W., Washington, D.C. 20036

RECOMMENDATIONS FOR A NATIONAL AIR TRAFFIC MANAGEMENT SYSTEM

Final Report
of the
Air Traffic Control System Planning Group

July 1969

Published by
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A Subsidiary of Aeronautical Radio, Inc.

FOREWORD

The horrendous and well-publicized delays experienced by all users of New York's metropolitan airports during the summer of 1968 spurred the Operations Conference Executive Committee of the Air Transport Association of America (ATA) to recommend that a special airlines' task force be established to develop long-range plans and recommendations for a future Air Traffic Control (ATC) system for the United States. Consequently, in November 1968, several well-qualified individuals from representative airlines were appointed to a working group to function under the jurisdiction of ATA's Air Traffic Control Committee. The group was designated the Air Traffic Control System Planning Group (ATCSPG) and given the following terms of reference:

"• Report to the ATC committee within six months, giving its recommendations on how today's ATC system should be remodeled to handle safely and efficiently the expected growth of aviation during the foreseeable future.

• Be wholly concerned with suggesting satisfactory long term solutions to ATC problems, at the same time bearing in mind that any changes, however radical, must be evolutionary in character.

• Endeavor to specify the respects wherein airports, navigation, communications, ATC facilities and ATC procedures should be improved to achieve, as soon as possible, the objective of an adequate and expandable ATC system, catering to all users of the airspace."

Representatives of the U.S. Armed Services, the Federal Aviation Administration, National Aeronautics & Space Administration, Aerospace Industries Association of America, Inc., and Aeronautical Radio, Inc., were asked to participate in the ATCSPG's sessions on a regular basis as observers; such participation was not to be construed as any form of commitment by the agencies represented, nor as endorsement of the ATCSPG's report. The ATCSPG decided to keep other civil users of the airspace informed on its work by distributing summaries of all its meetings and by asking such users to meet with the Group when its work had reached a suitable stage. The members of the ATCSPG, observers, and other participants in the sessions are identified in Appendix A.

At its first meeting, the ATCSPG summarized its objectives as follows: to furnish a realistic recommendation for an Air Traffic Control system that would meet the needs of all users in the United States. It was emphasized that the Group's purpose was not intended to conflict with the work of the Department of Transportation's Air Traffic Control Advisory Committee; however, it was hoped that the ultimate recommendations — made by the prime passenger common-carrier industry of the United States — would be of value to that committee and to other interested agencies.

Since the members of the ATCSPG were all engaged in airline operations, it was agreed that technical briefings and literature that might assist the Group in arriving at practical recommendations would be requested from within the air-transport industry, from the Federal Aviation Administration, and from other pertinent organizations and corporations. Consequently, this report culminates extensive discussion and analysis of all aspects of the ATC problem and its solutions, based on the experience of the ATCSPG members' own airlines and on inputs from competent observers, technical briefings, and relevant literature.

ACKNOWLEDGMENTS

The Air Traffic Control System Planning Group acknowledges with thanks the valuable contributions made to this report by briefings from the following organizations and persons:

- **Aeronautical Radio Inc. and ARINC Research Corporation** — Messrs. J. S. Anderson, Chairman of the Board; J. F. Taylor, President; W. W. Buchanan; J. B. Rivera; and B. C. Retterer; a briefing on aeronautical communications technology.
- **Butler National Corporation** — Mr. G. Gilbert, Consultant; a briefing on the company-developed report *An Advanced Program for Air Traffic Control System Improvement.*
- **Department of Transportation** — Mr. B. Alexander and Dr. L. Goldmuntz, Chairman and Executive Secretary, respectively, of DOT's ATC Advisory Committee; a briefing on their approach to a future ATC system.
- **Federal Aviation Administration** — Messrs. Shipp and Burch of the Atlanta, Ga., Control Tower; a briefing on the ARTS—I Program. Mr. Herman of the Systems Research and Development Service; a briefing on the DAIR Program. Mr. Mercer of the Systems Research and Development Service; a briefing on the ARTS—II & III Program. Messrs. R. F. Frakes and R. M. O'Brien of the National Airspace Systems Program Office; a briefing on the FAA NAS Stage A Automation Program. Messrs. Boyle and Rubenstein of the New York Air Route Traffic Control Center; a briefing on the Center's operations. Mr. L. Leon of the New York Common IFR Room; a briefing on the IFR Room's operation.
- **Lincoln Laboratory, Massachusetts Institute of Technology** — Messrs. H. G. Weiss and J. M. Ruddy; a briefing on their report *A Concept for Air Traffic Control.*
- **McDonnell-Douglas Corporation** — Mr. A. Browde; a briefing on the application of time frequency technology in ATC.
- **Pan American World Airways** — Messrs. B. F. McLeod and R. R. Bohannon; a showing of a film on data-link experiments being conducted by Pan American.
- **Port of New York Authority** — Messrs. J. Wiley and L. Atchitoff; a briefing on airport problems in the metropolitan New York area.
- **Sikorsky Aircraft** — Mr. J. T. Stultz; a briefing on a new concept for aircraft separation standards with regard to VTOL & CTOL high density air traffic operations.
- **TRW** — Messrs. J. Murcklen, F. Gedicks, and D. Otten; a briefing on the application of satellite technology to the air transportation system.

The Group also acknowledges with appreciation the following organizations for their assistance and for the use of their facilities:

- Aeronautical Radio, Incorporated, Annapolis, Md.
- Delta Airlines, Atlanta, Ga.
- Piedmont Airlines, Winston-Salem, N. C.
- United Airlines, New York, N. Y., and Washington, D. C.

SUMMARY

The United States airlines recognize that the current air-traffic-control/airport complex that serves them, as common carriers, has serious inadequacies that are detrimental to the capacity, safety, and growth potential of the national aviation system and to the efficiency and economy of the aviation industry in general. They recommend that the airspace be restructured to eliminate the current unsatisfactory mix of uncontrolled and controlled flights, and that a minimum "price of admission" be specified for all aircraft electing to fly in controlled airspace. Further, they recommend that the ground Air Traffic Control (ATC) function be completely automated and that voice communications between ATC and aircraft, except those communications for specialized or emergency purposes, be replaced by automatic digital communications.

To expand system capacity, the airlines recommend that aircraft-separation standards be reduced and improvements be made in the airborne guidance-and-control system for aircraft operating in congested megapolitan areas. They stress the advantage of an accurate and reliable system of position determination to serve both navigation and ATC purposes, the need for increasing airport capacity by improving airport design, and the need for building airports in sufficient numbers to meet the traffic demand.

There must be no delay in obtaining national accord on how a new, expandable system for air-traffic management should be constructed. Funds must be appropriated and targets set to permit the processes of design, procurement, evaluation, and commissioning to proceed on a firm and expeditious time schedule. The airlines recognize the many difficulties associated with changing from today's ATC system to one geared to the real needs of the times and of the future. However, immediate steps must be taken, and one element of the transition process must be early relief of the current situation.

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CHAPTER ONE

INTRODUCTION

The Air Traffic Control System

As defined in Federal Aviation Regulations, Part 1, Air Traffic Control is "a service operated by appropriate authority to promote the safe, orderly and expeditious flow of air traffic." The provision of this service involves the myriad interrelated elements that have been combined by an evolutionary process over the years to form what is now generally called the Air Traffic Control (ATC) system. This system grew — it was never designed as an entity. It is extremely complex and constantly undergoing changes, partly because of the diverse requirements of the various users of the airspace, and partly because of the continuous increase in traffic volume and the ever-changing nature of the vehicles that comprise the traffic.

Although continuous modifications to the ATC system have resulted in improvements, the pressing need for accelerating the improvement process is recognized by all concerned. There is less unanimity, however, when it comes to discussing what should be done; there are even differing views on what exactly is meant by "the system".

In its broadest sense, "the system" involves airports, various types of facilities, rules, and procedures. It also involves the airspace itself — the manner in which it is subdivided for different uses, the rules and procedures governing flight within its different categories, and the variety of techniques and devices (some ground-based, others self-contained within the aircraft) used for navigating through it. The ATC system uses a complex of ground equipment, airborne equipment, personnel, communications, navigation aids, displays, radar, computers, and airways. It involves circulating an abundance of papers containing flight information, criteria, regulations, and procedures, all aimed at making the system function according to certain established ideas of how operations should be conducted.

Flight Operations

Until recent years there were only two basic modes of flight operation. The first — the "see-and-be-seen" mode — is predicated on the assumption that pilots flying in certain specified weather conditions can see and can be seen by the pilots of conflicting traffic: the pilots themselves, therefore, can take the necessary evasive action to avoid collision. Federal Aviation Regulations governing such operations are known as Visual Flight Rules (VFR). When weather conditions are below the minima specified for VFR, all pilots operating in designated ATC-controlled airspace must abide by Instrument Flight Rules (IFR)and obtain prior approval to proceed in the form of a clearance from ATC; this constitutes the second mode of operation. In brief, in the second mode, aircraft separation is afforded by ATC in certain specifically designated airspace. This mode is concerned primarily with traffic operating under IFR.

Scheduled air-carrier jet transports must, by Federal Air Regulations, fly IFR under ATC jurisdiction whenever they are operating in controlled airspace — even when VFR weather conditions prevail. Other aircraft, however, have the option of flying VFR or IFR when operating in controlled airspace under VFR weather conditions*. Consequently, in good weather (VFR conditions), some traffic in controlled airspace is controlled and some is not, and the pilots flying IFR under ATC jurisdiction must also abide by the principles of "see-and-be-seen" because other traffic in the same airspace may be operating VFR and may be unknown to ATC. In essence, there is a system of divided responsibility during good weather conditions: some pilots assume the obligation to see-and-avoid all other traffic, while others rely on ATC separation for avoiding similar traffic but remain responsible for seeing and avoiding VFR (nonparticipating) traffic. Furthermore, because humans cannot measure visibility accurately under all conditions, there are often differences of opinion among pilots as to whether VFR conditions prevail or not.

During recent years there has been a growing concern regarding the ability of pilots to see and avoid all other potentially conflicting traffic, even though operating in unlimited-visibility conditions. This concern, deepened by the advent of higher performance aircraft and the large increase in traffic volume, led to the development of a third mode of operation known as "positive control". This mode requires *all* aircraft within certain specified airspace to operate under ATC jurisdiction for the purpose of collision avoidance, regardless of weather conditions — no VFR operation or uncontrolled flight of any kind is permitted within "positive control" airspace.

Beyond the boundaries of the controlled airspace, there are large volumes of airspace in which no ATC service is provided. In this uncontrolled airspace, pilots are afforded no separation service by ATC, whether they are operating under VFR or IFR. Only the general rules governing cruising altitudes according to direction of flight provide any semblance of segregation between all types of traffic — VFR, IFR, opposite direction — while in level flight. In essence, separation within uncontrolled airspace depends, during VFR weather conditions, on a pilot's seeing and avoiding other flights, and, during IFR weather conditions, on sparsity of traffic and chance.

Because of the constantly increasing traffic volume, the increased performance capabilities of newer aircraft, and the growing diversity of operations being conducted by aircraft operators, the airline industry considers an efficient ATC service to be the most practical method of avoiding mid-air collisions. To safeguard their customers, the airlines are currently seeking the protection of ATC separation (a) in IFR weather conditions for all their flights and (b) in all weather conditions for their flights operating in airspace where the volume or nature of air traffic is such that sole reliance upon pilots' seeing and avoiding other traffic involves undue risk to the public.

Airborne Collision Avoidance Systems and ATC

For many years, the airline industry has fostered the development of a suitable airborne Collision Avoidance System (CAS) and Proximity Warning Indicator (PWI). However, its interest and activities in this field should not be misconstrued: as indicated previously, the airlines are convinced that a positive, fail-safe Air Traffic Control system, under the jurisdiction of a central agency exercising control from established ground units, is the only

*This option does *not* apply in "positive control" airspace, which is discussed in the subsequent paragraph.

real solution to the mid-air-collision problem. In addition, the industry believes that such a system is essential to the efficient organization of traffic flow. Nevertheless, a CAS or PWI, when fully developed and proven, may have logical applications as an adjunct to the ATC system. For example, the possible ability of these devices to provide for efficient in-trail operations and for pilot awareness of nearby aircraft on approach to or departure from parallel runways may have valuable complementary applications. In no sense are such devices envisioned as substitutes for a well-conceived and efficiently operated Air Traffic Control system.

CHAPTER TWO

THE PROBLEM

The Operational Impact

All operators of civil aircraft rely on the Federal Government and airport authorities to provide and operate the ground facilities and ATC facilities essential to their task of serving the traveling public. Failure to forecast accurately the growth of air traffic and to anticipate the airways/airport system's inadequacy for handling traffic demand in key metropolitan areas has resulted in increasing congestion. The situation inflicts hardships on the traveling public, financial losses on the air carriers, and constraints on the economic growth of the surrounding community.

The current ATC system relies heavily on the skill and dedication of human air-traffic controllers who use radar for aircraft surveillance and sequencing, and voice communications for communicating with pilots. The lack of precise, automatic, and unambiguous information either in the aircraft or on the ground necessitates substantial human intervention that results in heavy workloads for both pilot and controller. Radar has been refined for ATC application, secondary surveillance radars have been introduced in elementary form, and processing and display systems providing three-dimensional position and identity information are just beginning to appear on the scene. Nevertheless, over the long term, the current primary/secondary radar systems have serious shortcomings. They are saturable, inefficient in information flow, and suffer interference from weather and other sources. Better, more accurate, more efficient, and more economical means of position determination must be developed for the future ATC system.

Airports and airport facilities have also failed to keep pace with traffic growth; the tasks of finding the necessary financing, obtaining agreement on the location of new jetports, and acquiring the necessary real estate inevitably take a long time. Furthermore, the capacities of most existing major airports are severely limited by noise-abatement procedures at certain times; similarly, construction and repair work are generating delays.

The ever-increasing demand on ATC voice-communications channels has led to communications congestion and, in conjunction with the limited capabilities of some airborne equipment, to consequent compromises in the frequency-assignment plan designed to avoid interference between signals.

In the absence of a short-term solution to the ATC system's deficiencies, aircraft operators are being penalized by arbitrary restrictions on traffic movement, and the imposition of undesirable limitations on the operating characteristics of their aircraft.

ATC and navigation service is not available for all the IFR operations that the airlines require. This is due partly to inadequate system capacity and partly to Government policies concerning the use or provision of navigation aids for public air-transportation service.

The inherent complexity of today's ATC system, as it struggles to handle the increasing demand for service, is spawning regulations and procedures that greatly increase the workload of controller and pilot. Risk of human error by misunderstanding or oversight is introduced; too often, the ATC system is forced to operate at the limit of its capability, so that even a small unanticipated event can upset the delicate balance of operations and cause almost total disruption of service.

A picture is revealed, then, of an ATC system that has been exceedingly slow to evolve. Responsible persons have failed consistently to tackle serious problems until they have become critical; patchwork fixes have been adopted with little apparent appreciation of the long-term consequences. When development work has been involved, there has been far too much delay in introducing equipment into service. Adding more controllers -- although necessary now — does absolutely nothing to solve the long-term problem: coordination between controllers is time-consuming and burdensome, and the addition of more controllers to relieve the workload generates a requirement for more coordination and, thus, eventually defeats the objective. At the same time, some procedures designed to minimize coordination have the disadvantage of decreasing flexibility and causing inefficient use of airspace.

Any satisfactory improvement plan must achieve a proper balance between short-term and long-term remedies. Methods must be found to effect limited early improvements while the development work necessary to effect longer-term improvements is pursued energetically and at an accelerated pace. In this process some new equipment must be applied without delay, even if it does not meet the longer-term goals.

There has been consistent failure to implement recommendations that have had Government endorsement. As long ago as 1948, an imaginative and far-sighted plan proposed by Special Committee Number 31 of the Radio Technical Commission for Aeronautics was endorsed by the Congressional Aviation Policy Board; it was never implemented. Other plans, such as those of the Air Coordinating Committee Special Groups 5 (1950) and 13 (1957), the Curtis Committee (1957), and the Project Beacon Task Force (1961) have been only partially implemented. Since then, misunderstanding of the problem and serious underestimation of the costs involved have resulted in a situation that is causing widespread national concern. The situation demands urgent attention at the highest Government and industry levels. Success in solving the problem will be measured in terms of the extent to which the future ATC system accommodates the requirements of all users of the national airspace and thereby fosters the natural growth of an industry that is vital to the nation's prosperity and economy.

The Economic Impact

The spectacular growth of air transportation is due basically to one unique feature — time-saving. Businessmen, Government administrators, the general public — all bent on traveling large distances in short periods of time at economical prices — have made air transportation the primary mode of long-distance travel in the United States. The time-saving capabilities of modern aircraft also have been responsible for large increases in air freight, a segment of the industry that is predicted to grow even more rapidly in the future. Unfortunately, the delays created by deficiencies in the ATC system, airports, and related facilities are inhibiting full capitalization on this unique characteristic of air transportation. Passengers and their families and friends are being inconvenienced and frustrated, the

aircraft operators are incurring large additional operating expenses, and the overall impact of poor performance on the current and impending tremendous capital requirements of the industry is serious.

Any circumstances that cause aircraft to deviate from their time schedules by more than a few minutes not only prevent the air carriers from providing a satisfactory service to the traveling public but also make it difficult for them to maintain the fare structure necessary for true mass transportation. Although an air carrier initially may accept lower profits or greater deficits to absorb the extra cost imposed by delays, sooner or later, even in a regulated industry, he must pass on this cost to the customers in the form of increased fares.

As traffic volume has grown, delays have increased proportionately. Recently, a study conducted by the airlines and the FAA estimated that the direct operating cost to the scheduled-airline industry due to terminal delays was approximately 60 million dollars in 1966, 75 million in 1967, and in excess of 100 million in 1968. One major airline estimates that flight delays (deviations from published scheduled times) caused primarily by ATC or airport deficiencies were responsible for additional direct operating costs of at least 24 million dollars in 1968. These figures do not include the additional direct cost of special passenger services such as hotel accommodations, meals, limousines, taxis, telephone calls, and telegrams. The intangible costs associated with loss of public confidence and restriction of growth must also be recognized as profoundly significant.

To maintain realistic schedule information for the benefit of its customers, the airlines already allow for many minutes of probable delay due to ATC problems. As an example, flights by today's jet airliners between New York City and Washington, D. C., should be able to meet a gate-to-gate schedule of 35 minutes; instead, because of deficiencies in the ATC system, a representative airline schedule shows gate-to-gate times that vary from 58 to 63 minutes. Moreover, the average operating time on the same sector has been increasing recently at the rate of one minute per month. (Charts illustrating the increase in terminal delays and the cost of such delays are included in Appendix B).

Under these conditions, then, it is not surprising to find that the high-performance, expensive aircraft acquired by the airlines are being operated between many congested-area city pairs with approximately the same gate-to-gate times that were achieved many years ago with slower and less expensive piston aircraft.

Since the FAA maintains only cursory and general records of ATC-associated delays, there are no accurate, definitive data concerning the economic impact of such delays on the aviation industry and the nation. It is reasonable to conjecture, however, that if the complete penalty, in terms of additional operating expense, inconvenience to the public, missed business appointments, alternative travel cost, etc., were known, it would be a staggering revelation to all concerned.

The Consequences of Continuing With The Current System

Recent experience indicates that an overall plan for an Air Traffic Management system capable of handling expected traffic growth must be formulated, adopted, and implemented if the aviation industry's growth is not to be stifled and if a generally unsatisfactory service is not to be offered to the public. The FAA itself has forecast that the number of airline revenue passengers will grow from 153,500,000 in 1968 to 470,000,000 in 1979 and that the scheduled-airline fleet will increase from 2388 aircraft to 3860 aircraft in the same

period. The same forecast predicts that the active general-aviation fleet will grow from 112,000 aircraft to 203,000 aircraft. (Current experience, incidentally, is showing that all such recent forecasts, regardless of source, have significantly underestimated the actual growth rate.) Charts that illustrate the growth of air traffic in the United States are included in Appendix B.

Although there are no exact statistics or forecasts for the number of uncontrolled flights in the United States, the FAA has provided counts and forecasts for all operations at airports with FAA ATC service. These indicate that in 1968 such airports handled 53,100,000 operations, of which 14,600,000 were under IFR; the forecast is for this ratio to be maintained through 1979. Moreover, investigations and discussions reveal that many current VFR movements would probably operate under IFR if the ATC system were capable of handling them without excessive delay. However, in high-density areas, the system has been proven incapable of handling even the current amount of IFR traffic without excessive delay and, even if funds and equipment were available for immediate expansion of ATC services on a short-term basis, it would not be feasible to proceed because sufficient trained controllers are not available. (The FAA estimates that it takes approximately two years to train an air-traffic controller.) Furthermore, all currently planned technical improvements, such as the NAS Stage A and the ARTS programs, which are expected to be implemented slowly with a completion date of 1972 or 1973, are not expected to increase capacity to the extent necessary to meet the projected air-traffic growth. However, these programs can provide the computer base on which future automation can be planned.

Additional airport runways, STOL ports, heliports, and general-aviation airports are also planned for high-density areas such as New York, but these too will offer no significant help prior to 1972/1973 at the earliest. Even then, to obtain any real increase in air-traffic capacity in such megapolitan complexes, it also will be necessary for the airspace users to equip their aircraft with area-navigation systems and for the FAA to develop the appropriate procedures and rules. These requirements are clearly indicated by the preliminary results of the FAA's radar and analytic simulations of the New York area in 1975, which assumed that 90 percent of the users were equipped with area-navigation systems.

While the current ATC system falls further and further behind the traffic-growth curve every year, remedies offered by its defenders are generally either restrictive, such as to rely on scheduling according to system capacity rather than public demand, or optimistic, such as to rely on the advent of the large jets (B-747, DC-10, L-1011, etc.) to reduce the number of aircraft involved. It should be noted with respect to the latter expectation that most of the smaller jets are being depreciated on the basis of at least 12 years of useful life and that the FAA forecasts predict a large increase in the air-carrier fleet and an even larger increase in the general-aviation fleet. Some individuals have advocated, contrary to traditional American ideas, less competition among the air carriers as a possible solution; others believe that high-speed rail passenger service may be the answer. The advocates of rail service minimize the difficulties and huge costs involved in implementing their ideas and disparage the fact that aircraft, whether STOL, VTOL, or CTOL, could offer better service to those to whom time is important, if the ATC system were capable of handling such aircraft properly. The very nature of these "remedies" indicates the seriousness of the crisis. By Government order and mutual agreement between the airlines involved, schedule restrictions have already been put into effect. The impact on the cities involved is small so far, but in the long run their economic well-being will be impaired.

The United States' air transportation network has become the major inter-city passenger common carrier and is vital to the movement of certain classes of cargo; general-aviation aircraft also contribute significantly to the national economy. Despite any immediate action by Government and the industry, growth in all segments of aviation will be restricted in the next decade by the lack of an adequate system for air-traffic management. It is vital that this restriction be eliminated as soon as possible. New approaches must be adopted and the best of modern technology harnessed to yield a viable and expandable system that nurtures rather than impedes the growth of the aviation industry.

CHAPTER THREE

RECOMMENDATIONS

RECOMMENDATION 1

Recommendation

The Air Traffic Management system should serve all types of civil and military aircraft.

Discussion

The airspace of the United States should be open to all aircraft including VTOL, STOL, and CTOL, whether general aviation, commercial common carrier, or military vehicles. More than one system would not be economical, inevitably would require difficult coordination, and, consequently, would be contrary to the national interest.

RECOMMENDATION 2

Recommendation

There should be two categories of airspace — uncontrolled and controlled, the latter divided into three types. The two categories are defined as follows:

- Uncontrolled Airspace — Airspace in which all aircraft are outside the active jurisdiction of ATC. Separation is achieved only by compliance with the rules of the air applicable to this airspace.
- Controlled Airspace — Airspace in which all aircraft are under the jurisdiction of ATC for the purpose of receiving separation service. The nature of this service will vary, depending on whether the aircraft is an *active participant* or a *passive participant* in the ATC system.

Definitions:

- *Participant* — An aircraft in controlled airspace whose identity, position, and altitude is made known to ATC, preferably automatically, without human intervention.
- *Active Participant* — An aircraft operated along flight paths specifically assigned or approved by ATC in response to a flight plan.
- *Passive Participant* — (a) An aircraft operated along flight paths that are chosen by the pilot or operator and that are made known to ATC, which in turn provides traffic advisories to the aircraft, or (b) an aircraft that does not make its intentions known in advance to ATC and, therefore, does not receive traffic advisories.

Controlled airspace should be subdivided as follows:

- **Type 1 Airspace — Segments within which the density or nature of operations is such that ATC is responsible for providing separation service between all aircraft. Accordingly:**

  1. **All aircraft must be *active participants***
  2. **Regardless of weather conditions, all operations must be conducted according to flight plans for which prior ATC approval has been obtained.**
  3. **Identity, position, and altitude of all aircraft must be known to ATC.**
  4. **All aircraft must be in two-way communication with ATC, preferably by automatic means.**

- **Type 2 Airspace — Segments within which the density or nature of traffic is such that ATC is responsible only for providing separation service between (a) *active participant* and *active participant* and (b) between *active participant* and *passive participant*. Separation between *passive participant* and *passive participant* will be the responsibility of the pilots, aided by ATC service in the form of traffic advisories. Accordingly:**

  1. **Active participation is required only when the specified weather conditions prevail, but aircraft may elect to participate actively during any weather conditions.**
  2. **When specified weather conditions prevail, passive participation will be permissible even though some aircraft may choose active participation. When weather conditions do not permit passive participation, all traffic must become *active participants*.**
  3. **All operations must be conducted on a flight plan, regardless of weather conditions. However, only *active participants* need obtain prior ATC approval.**
  4. **Identity, position, and altitude of all traffic must be known to ATC.**
  5. **All aircraft must be in two-way communication with ATC, preferably by automatic means.**

- **Type 3 Airspace — Segments within which traffic density is significantly less than that in Type 2 Airspace, but in which ATC is still responsible for providing separation service between *active participant* and *active participant* and between *active participant* and *passive participant*. Separation between *passive participant* and *passive participant* will remain the responsibility of the pilots, without the benefit of traffic advisories from ATC. Accordingly:**

  1. **Active participation is required only when the specified weather conditions prevail, but aircraft may elect to participate actively during any weather conditions.**
  2. **When specified weather conditions prevail, passive participation will be permissible even though some pilots may choose active participation. When weather conditions do not permit passive participation, all traffic must become *active participants*.**
  3. **Operations by *active participants* must be conducted on a flight plan for which prior ATC approval has been obtained. No flight plan is required of *passive participants*.**

4. Identity, position, and altitude of all aircraft must be known to ATC.
5. *Active participants* must be in two-way communication with ATC, preferably by automatic means. *Passive participants* must have at least two-way voice communications with ATC.

Discussion

Increased traffic in congested areas and the introduction of high-performance aircraft militate against continuing to place sole reliance for collision avoidance on pilots' vision. Implicit in Recommendation 2 is the need to develop a relatively simple and low-cost airborne device that can provide three-dimensional position and identity information to ATC, and that is capable of being carried eventually by all aircraft flying in controlled airspace. Receiving equipment would be deployed to process signals from these devices and automatically transmit the necessary information to ATC's data-processing units. Technical presentations to the ATCSPG have led to the conclusion that there are several techniques for achieving this objective within today's state of the art. It is urged that imaginative technology be applied to find the optimum technique.

The elements of Recommendation 2 are summarized in Table 1.

Table 1. SUMMARY OF TYPES OF CONTROLLED AIRSPACE

		Type 1 Airspace	Type 2 Airspace	Type 3 Airspace
Participants Permitted		Active	(a) Active (b) Passive if weather permits	(a) Active (b) Passive if weather permits
Requirements	Flight Plan	Flight plan and prior ATC approval required	(a) Flight plan and prior ATC approval required for active participants (b) Flight Plan but no ATC approval required for passive participants	(a) Flight plan and prior ATC approval required for active participants (b) Flight plan not required for passive participants
Requirements	ATC Data	Identity, position, and altitude	Identity, position, and altitude	Identity, position, and altitude
Requirements	Communications	Two-way communications, digital or voice	Two-way communications, digital or voice	Two-way communications, at least voice
ATC Service Provided		ATC provides separation service between all active participants (i.e., all aircraft in this airspace)	ATC provides separation service between all active participants and between active participants and passive participants. ATC provides traffic advisories to passive participants to assist them in their responsibility to maintain separation between themselves and other passive participants.	ATC provides separation service between all active participants and between active participants and passive participants. Passive participants are responsible for separation between themselves and other passive participants.

RECOMMENDATION 3

Recommendation

Operational control should remain the sole prerogative of the aircraft operator. To assist this function, airborne and ground digital communications systems should be compatible with operational-control requirements.

Discussion

While the system will require discipline, it should not usurp the operators' jurisdiction over decision-making commonly known as operational control. Each operator has the best understanding of his own needs, and any attempt to assemble in the system the equivalent of the operators' vast store of knowledge would be practically impossible. Much of the information needed by the Air Traffic Management system is also needed by the user for operational-control purposes, and, consequently, should be easily obtainable by him through automatic means. In short, to avoid expensive duplication of equipment, the system should be designed to have as much technical commonality with the users' operational-control systems as is practicable.

RECOMMENDATION 4

Recommendation

Predetermined and segregated flight paths, with associated arrival and departure facilities, should be established where necessary for accommodating aircraft with different operational characteristics, such as speed range, fuel-consumption rate, climb and descent rates and angles, and runway-length and -strength requirements.

Discussion

Even now, handling mixed-performance traffic in congested terminal areas constitutes a serious problem, but the inevitable and ever-increasing use of VTOL and STOL aircraft in megapolitan areas emphasizes that the measures proposed in Recommendation 4 are needed to ensure that widely varying types of aircraft are operated with safety and efficiency. A highly accurate three-dimensional navigation system coupled with better methods of processing and displaying navigational-guidance information is needed so that the flight paths can be flown independently and with sufficient precision to enable separation standards to be reduced significantly. This will permit more efficient use of existing airports and, as additional STOL and VTOL landing areas become available throughout megapolitan areas, will ease (a) the increasing demand on existing jetports and (b) the problem of finding real estate for additional jetports near the hearts of the cities.

RECOMMENDATION 5

Recommendation

All aircraft that come under the active jurisdiction of ATC or that will seek service from ATC should be equipped with such devices as will enable ATC to function efficiently for the particular conditions involved. This is not to say that all aircraft must be equipped equally, but that each aircraft must be able to perform as required by the system.

Discussion

This recommendation supplements the airspace-structure recommendations of Recommendations 2 and 4. It recognizes the practical need to keep the "price of admission" to controlled airspace as low as possible in the interests of a large section of the aviation community, but imposes an obligation on every participant to meet necessary equipment and pilot-proficiency standards for the particular environment in which he proposes to operate.

RECOMMENDATION 6

Recommendation

The configuration of the airspace structure should be capable of being modified rapidly to accommodate variable conditions, such as air traffic density, special needs for short-term reserved blocks of airspace, or meteorological anomalies.

Discussion

Configuration flexibility should be inherent in the ATC system to provide for efficient use of the airspace by the various classes of users. While it is recognized that it is desirable to apply a certain amount of rigidity to the airspace structure, the ATC system should be capable of accepting dimensional changes by simple selection processes. Application of such changes should be controlled procedurally.

RECOMMENDATION 7

Recommendation

The system should enable an operation to be planned and executed on the basis of an accurate landing time's being allocated in response to a flight plan and should enable this time to be adjusted quickly and efficiently to meet unforeseen circumstances.

Discussion

Arrival times of sufficient reliability to permit the traveling public and the operators to plan their activities efficiently are essential. Achievement of this reliability implies more user self-discipline in the form of: (a) adequate precoordination to assure better utilization of the runway/time availability, (b) immediate advice to the system of any changes in flight plans, both prior to departure and throughout the flight, and (c) acceptance of the fact that operating and scheduling practices must be adjusted to less than optimum levels on occasion. It also implies the existence of an air traffic management system that is capable of handling, without excessive delay or other penalty to the user, the immense amount of continuously changing data affecting arrival times. It is realized that a very limited amount of airborne holding probably will be necessary in very-high-density terminal areas to insure that capacity is fully utilized at all times. The better planning made possible by reliable arrival times will more than adequately compensate the users for the cost of such holding.

RECOMMENDATION 8

Recommendation

All routine ATC functions — including at least planning, monitoring, conflict

prediction, and avoidance — should be handled by a suitably constructed and programmed data processor, with the human air-traffic controller exercising only a supervisory function.

Discussion

A major weakness in today's ATC system is the inability of manual control practices to handle efficiently the current traffic volume in congested areas. Adding more controllers and segmentation of airspace as traffic builds up merely compounds the problem by generating unacceptable difficulties in coordination and communications. Modern computers, however, can be programmed to process and communicate at high speed the vast quantity of information involved. Therefore, widespread automation constitutes the only feasible method of handling the diverse and ever mounting volume of air traffic predicted for the years to come. Traffic controllers should be relieved of all routine functions and be required to discharge only those duties for which human judgment can be utilized best. Consequent reductions in workload and stress will lead to more efficient operations and considerable economies in operating-system costs.

RECOMMENDATION 9

Recommendation

The responsibility for navigation should rest with the pilot, who should have three-dimensional navigation guidance sufficient to permit him to conduct this task within the allocated designated airspace. The responsibility for safe and expeditious flow of traffic should rest with the ATC service, and this service should be based on accurate and reliable three-dimensional position and identity information for all aircraft of concern. There is a need, then, for a single overall system of position determination that has sufficient accuracy, reliability, and integrity to serve both the aircraft and ATC.

Discussion

In today's ATC system, the controller generally uses radar-derived position information to carry out his function. Also, because of limitations in the existing airways structure based on VOR radials, radar is used extensively as a navigation tool to provide vectors for the pilots. This system requires excessive workload for both pilot and controller and also uses an inordinate number of communications channels, which are in short supply. The navigation system of the future may depend on ground-, satellite-, or air-derived information, or on a combination of these. It should be designed as a complete, reliable, and accurate system to monitor the progress of the aircraft. Aircraft-position information required by the pilot and the ATC system to carry out their respective functions are identical, since mid-air collisions only occur when two aircraft are navigated to the same point in space at the same time. A common system of position determination automatically communicated in digital form to the ground represents the most economical and efficient means of satisfying both requirements.

RECOMMENDATION 10

Recommendation

The system should include a capability for the ground data processor to obtain automatically, without human intervention, and at all times from gate departure to gate arrival the identity, position, and altitude of aircraft, so that it can handle all traffic with *optimum efficiency and safety.*

Discussion

This recommendation — and several others — is based on automatic air/ground/air digital communications. Out, off, on, and in times are required to assist in the control of airport ground traffic, and to obtain statistical data concerning system efficiency.

RECOMMENDATION 11

Recommendation

The system should enable the pilot to communicate, via a suitable input device and the digital communications system, pertinent routine messages to ATC and operational control. Additionally, all ATC instructions necessary to maintain a safe and efficient traffic flow should be generated by the data processor and transmitted automatically to the aircraft. Voice communications should be retained and reserved for specialized and emergency purposes.

Discussion

Replacing routine ATC voice communications by a digital communications system will improve safety and efficiency and effect a major reduction in pilot/controller workload. Further advantages are the elimination of errors due to a fundamental lack of clarity in voice communications, the ability to exchange information at a faster rate between the air and ground subsystems, the ability to store information in hard copy or by a similar system of recording essential information, and conserving the use of the frequency spectrum. Speedy and reliable digital communications facilitate automatic updating of information essential to efficient flight operations and ground monitoring of traffic progress.

A discussion paper on communications for a future ATC system is included as Appendix C.

RECOMMENDATION 12

Recommendation

The system should enable the aircraft to accept and carry out ATC instructions automatically; the information should be suitably displayed in the cockpit to enable the pilot to exercise his command function.

Discussion

This recommendation arises directly from the need to reduce workload on the ground and in the air and to eliminate unnecessary time lags in responding to system demands. Instructions to the aircraft from the ATC data-processing system should be sent via the ground/air digital communications system. These instructions should direct the aircraft, through its airborne computer and navigation system, to proceed to a defined point in space. As a preliminary step toward the ultimate objective of a fully automatic system, the aircraft could be guided manually by the pilot after receiving the ATC instructions. In both manual and automatic modes, the pilot must be kept fully informed so that he can exercise his command responsibilities and be able to accept or reject the instructions in the interest of safety or in the event of a malfunction.

RECOMMENDATION 13

Recommendation

The system should enable the pilot to navigate along any operationally desirable flight path with the accuracy needed to comply with both ATC and operational requirements.

Discussion

Airborne computers provide the pilot with the ability to follow any predetermined track from takeoff to arrival, with external reference aids providing only sensory inputs to the computer. Consequently, the complete navigation function can be performed from the cockpit, and ATC can revert to its purpose of monitoring traffic movement to provide separation service and organize an expeditious flow rate. The impending importance of being able to follow three-dimensional flight paths and make curvilinear approaches and departures renders it necessary also to feed altitude information into the airborne computer, which can then provide the pilot with the direct guidance to fly such flight paths. This ability is particularly important to the success of VTOL and STOL operations, and will provide an additional separation ingredient for use by the ATC system. A suitable method of storing in the airborne computer all the information needed to carry out a complete flight from gate departure to gate arrival should be developed to reduce workload and increase efficiency.

RECOMMENDATION 14

Recommendation

The system should permit the use of an airborne guidance-and-control system that displays to the pilot in real time all the information necessary to his command function. The following information should be displayed:

- Continous geographical position of the aircraft and a continuous guidance command
- ATC clearance, including details and revisions thereto
- Information concerning runways, surface wind, RVR, adverse weather, etc. (available for display in a recallable form)
- Information on pertinent traffic (displayed in three-dimensional form)

Discussion

The features described in this recommendation are necessary to achieve the flight precision essential to the most efficient use of available airspace in congested areas. A suitable display solves the pilot's orientation problems and eliminates the need for controller vectoring. The visual display of essential flight information will reduce workload and promote efficiency. Displaying the relative position of adjacent traffic will enable the pilot to monitor separation and help maintain a high flow rate in congested areas. Research should be directed toward developing an integrated cockpit display that enables the pilot to carry out his responsibilities for guidance and control with the necessary precision.

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RECOMMENDATION 15

Recommendation

To increase system capacity, modern technology should be used to reduce separation standards, consistent with safety.

Discussion

The capacity of a single flight path carrying traffic in-trail is directly proportional to the velocity of the aircraft through the system and inversely proportional to the separation. Since velocity is constrained either by aircraft performance standards or economy measures, separation is the major candidate for redetermination. The current separation standards were adopted rather arbitrarily based on the limitations of the existing ground and airborne system. This recommendation, therefore, is predicated on the ability of current technology to improve detection resolution to a point that separation standards can be reduced significantly without sacrificing acceptable levels of safety.

Separation is limited fundamentally by the physical size and the operating characteristics of the aircraft. To these basic limitations must be added a factor to account for the uncertainty associated with imprecision in navigation accuracy, which is a function of ability to detect distance displacement, velocity, and acceleration. Coupled with the minimum displacement sensitivities is the aircraft/pilot system's response time required to restore the aircraft to a prescribed position when a displacement error has been detected. The ability of the aircraft to maintain prescribed flight paths is a further limiting factor. The aircraft/pilot system is influenced by such external agents as air turbulence and wind, which may cause excursions beyond a prescribed route and thus introduce perturbations that exceed the system's capability to respond. These perturbations must be considered in separation calculations.

An automated ATC system will make greater use of automatic flight control. This will speed system response and thus increase the precision of aircraft control. The faster response will decrease the magnitude of absolute correction needed and thus permit closer control, still within the limits of passenger comfort. The more precise control afforded by an automated system is further justification for separation reduction.

The real-time system monitoring afforded by a computer-based ATC system should further decrease separation requirements. The continuing position inputs from each aircraft under jurisdiction will enable the computer to detect possible conflicts more rapidly and thus afford much greater response times. Response time that is found to be in excess of safety criteria may be converted to an increment of separation reduction.

Development of separation standards must consider the increased capacity that elements of the system must accept if higher density is achieved; airport capacity and the capacity of the ATC system must be evaluated carefully to assure compatibility. Finally, it will be necessary to revise the governing rules and procedures to take full advantage of any separation reduction realized.

In summary, improved navigation accuracy and automation in aircraft and ground ATC subsystems can be used effectively to decrease the separation standards now in use by ATC. More efficient use of airspace is essential to the proper development of the necessary flight paths and landing areas for all types of aircraft that will be operating in congested areas. This increased efficiency will increase significantly the capacity of the ATC system.

RECOMMENDATION 16

Recommendation

The system should be capable of handling aircraft that are equipped with an airborne guidance-and-control system for operations to and from suitable runways on all desired airports under all operational weather conditions.

Discussion

Efficient and continuous operation on the basis of planned landing times will not be possible unless all runways can be used under all operational weather conditions. This does not imply that ground-based precision-approach aids are required for all runways; it does mean that runways lacking such aids must be put to maximum use to optimize traffic flow. Implementation of this recommendation will require navigation systems that adapt to curvilinear approaches, e.g., while one aircraft is approaching straight-in to a precision-approach runway, another curved approach could be conducted to another runway with proper separation and spacing for landing.

This recommendation is related to an airborne guidance-and-control system that insures a smooth and continuous transition. Today's system does not allow efficient operation to all suitable runways under all operational weather conditions, even with all approach aids on the ground operating normally. Due to the lack of backup in the current system, any outage inevitably will slow up the landing rate, cause traffic congestion, reduce airport utilization, and may generate a need for traffic diversions.

RECOMMENDATION 17

Recommendation

Sufficient properly designed airports and associated facilities should be provided to keep pace with the forecasted increase in all forms of air traffic and the more efficient use of airspace expected from the future ATC system.

Discussion

Airports and associated facilities are an essential part of the air traffic management system. Deficiencies in ATC or airport organization will have a significant effect on system capacity. Because final limitation to traffic growth is the capacity of the available runways in instrument conditions, ATC development should be planned to serve those runways at the maximum rate. A suitable complex of airports of all required types must be planned to serve the community's aviation interests and those of the traveling public.

All aspects of airport design should receive adequate attention. In particular, methods of achieving maximum runway/taxiway usage and of implementing new configurations capable of handling the desired volume of traffic, including closer spacing between parallel runways, should be devised. Usable gate space is an important element of airport design and should always be given full consideration.

Current runway-occupancy times at major airports are too high. The precision with which aircraft can be predicted to arrive at the threshold and the speed with which the runway can be vacated govern the number of aircraft that a given runway can handle. Consequently, an improvement in high-speed exits and in runway entrance systems capable of being used by future large transport aircraft is desirable.

RECOMMENDATION 18

Recommendation

There should be a standard automated airport surface guidance-and-control system for routing and controlling all traffic on the operational areas of the airport surface. Such a system should provide its position information and guidance commands in a manner suitable for integration with the aircraft's guidance-and-control system.

The system should function equally well in low visibility or good visibility, at day or at night, and during snow, slush, or rainy conditions. It should h e the following characteristics:

- Serve all runways
- Serve all taxiways
- Lead to or from parking areas, hangars, gates, or loading areas, but not be required to function within these areas
- Be properly integrated with the ATC system for the exchange of pertinent information
- Not rely on voice communications
- Be installed at major airports

Discussion

The problem of handling aircraft and vehicles on the surface of a bus, airport is often neglected. The task involves routing of traffic to establish proper flow, and clearances or instructions to avoid traffic conflicts or collisions.

Even during the best of weather conditions, and especially at night, it is sometimes difficult for pilots to identify visually the pertinent taxiways or complicated routin prescribed by "ground controllers" in voice communications. As traffic volume ar traffic-movement rates increase, the tempo of voice communications increases, which aggravates the situation. Sometimes, when the workload exceeds the capability of one controller, the function is handled by two controllers — each using a different communications channel. This necessitates channel changing in the cockpit if the aircraft proceeds from one controller's area of jurisdiction to another.

In many instances the complete airport movement area cannot be seen by the controller, sometimes because of intervening structures, and sometimes because of low visibility weather conditions. Visual perspective is hampered by long distances. As airports grow larger, the limitations of visual control are amplified

While the number of airport maintenance vehicles on active taxiways and runways is generally held to a minimum, larger airport complexes will necessitate the use of more vehicles to keep abreast of routine maintenance. Control and routing of these vehicles must be maintained. Additionally, emergency vehicles must find their way or be guided to emergency scenes, while other traffic is instructed to give way.

The current system is barely tolerable and it will become increasingly more limiting. An efficient automated airport surface guidance-and-control system will reduce pilot and control-system workload, increase airport capacity, and improve safety.

RECOMMENDATION 19

Recommendation

Actual weather information and significant in-flight weather reports should be entered rapidly and automatically into the ground data processor to assist the ATC planning function.

Discussion

Severe weather phenomena, such as thunderstorms and their associated turbulence and other flight hazards, can seriously affect the capability of the ATC system, because of user requirements for rerouting, increased separation, etc.

RECOMMENDATION 20

Recommendation

The ATC system should be capable of continuing in safe operation despite breakdowns in individual elements of the system. An uninterruptible power system must be provided for all ATC elements sensitive to power fluctuations.

Discussion

The increased dependence of ATC on automatic control will require appropriate reliability. Sufficient component redundancy to provide an adequate safety level and to prevent serious system disruption because of equipment failure either in the aircraft or on the ground must be provided.

RECOMMENDATION 21

Recommendation

The *effectiveness of* the ATC system should be monitored continously to enable corrective actions to be undertaken promptly. Daily summary performance data should be available to system users.

Discussion

Currently, the FAA maintains only cursory and general records of ATC-associated delays. These are insufficient for measuring the performance of the system. Various airlines collect a variety of delay information, but only a portion of such data ever reaches the FAA. Even then, there is no organized plan for use of this material on a continuing basis. Consequently, there is no accurate overall delay data that represents impact on the total aviation industry.

Current traffic counts and hourly traffic data acquired manually by FAA control-tower *personnel require tremendous manpower* and often fail to show the necessary breakout of user categories. Such data are essential for assessing system effectiveness and must be available on a daily basis.

CHAPTER FOUR

SYSTEM IMPLICATIONS OF THE RECOMMENDATIONS

The recommendations in Chapter Three were drawn up by the ATCSPG to give guidance on the manner in which the future system should be planned from an operational standpoint. In the Group's opinion, use of the systems approach that has been employed successfully in military and space programs is mandatory if a satisfactory long-term solution to one of the most complex and difficult problems of this age is to be reached. There is no apparent alternative to the full application of automation on the ground and in the air, with humans undertaking a passive and supervisory role. Airline managements are well aware of the cost and difficulty of developing and implementing real-time computer-controlled systems such as those now used in many of their reservations, communications, and flight-operations departments; at the same time, they are aware of the reductions in manpower and increased efficiency achieved by such systems. The reasons for applying computer-based data processing to these systems are similar to those that now prompt the ATCSPG to recommend that the future ATC system use this type of data processing on a grand scale. There are two distinctions to be made, however: (1) the ATC system's needs are far more pressing than were those of the other systems mentioned, and (2) in the ATC system, there can be no compromise with reliability or integrity, since one of the system's essential services is the provision of safety.

It is realized that certain details of the very sophisticated airborne guidance-and-control system that is advocated may be difficult to design, even in this era of advanced technology. Small solid-state computers, linked directly to the aircraft's automatic flight-control system, will be the operational heart of the airborne subsystem. At high speed and in real time, they will process instructions from the ground computer system and navigational data from appropriate sensors, and actuate integrated cockpit displays required by the pilot. Integrated displays that provide the pilot with all the data needed for his command function will become increasingly important as the airborne subsystem's capability is developed. There is a real need for imaginative design efforts in this very important field. Airborne computers and ground computers will communicate directly with each other via a digital data link, and pilots will be able to communicate with either computer through a suitable input device. The very promising position-determination systems that will use satellite technology, the time-frequency techniques being considered for CAS application, and the variety of trilateration systems being discussed should be studied thoroughly and a Government decision reached on the most suitable methods for replacing existing navigation systems and primary and secondary radar systems to meet future requirements of all airspace users, both civil and military.

The responsibility for navigation should rest with the pilot; the responsibility for organizing a safe and expeditious flow of traffic should rest with the ATC controller. The exercise of both responsibilities requires reliable, accurate, and continuous aircraft-position determination in both the horizontal and the vertical planes. The degree of accuracy and

continuity required by the pilot and the controller is a function of the desired separation standards, and must enable those standards to be applied in a safe fashion. To hold to a minimum the cost of operating an efficient and safe ATC system, a single system of position determination that serves the requirements of both pilot and controller should be used.

The ability to measure accurately the vertical distance between adjacent aircraft and to improve altitude measurement should be sought vigorously. To accomodate small, private aircraft, a lightweight, low-cost airborne beacon should be developed, so that at least the identity, altitude, and position of every aircraft in controlled airspace can be obtained on the ground. To reduce landing and takeoff constraints imposed by reduced visibility, better operational capability must be sought; aircraft operations should be segregated according to aircraft performance characteristics, class of ATC service required, and equipment aboard the aircraft. To use airspace economically and all runways to maximum capacity in congested areas, a multiplicity of closely spaced non-conflicting flight paths must be established; these should be based on effective coordination of user interest and system requirements. The ability to follow such paths and to meet a predetermined arrival time without excessive workload for the pilot or ATC controller is an essential element of the airborne guidance-and-control system advocated by the ATCSPG.

The ground ATC subsystem will function around a data-processing complex programmed to receive and handle all the data required to monitor the traffic flow and to generate the displays and information needed by the controller in his new supervisory capacity. The ground data processor's information concerning the position of individual aircraft could be transmitted automatically to airline control centers for planning and passenger-information purposes.

The new ATC system should be designed with the objective of placing the responsibility for compliance with its management requirements firmly in the cockpit; the ground subsystem should be concerned only with planning and monitoring the traffic flow. The ATCSPG believes that the disadvantages accruing to the operators by the imposition of a greater measure of discipline will be outweighed by the beneficial increase in terminal-area capacity and the establishment of multiple enroute flight paths. The latter benefit will result in significant economies in fuel and time because of optimum aircraft utilization.

Airports and their facilities and the traffic capacity of the airspace must receive balanced consideration, because either or both can represent the final limitation on traffic growth. VTOL and STOL aircraft must use the same air traffic management system as CTOL aircraft; consequently, the future ATC system must meet the special requirements of these aircraft.

The ATCSPG is well aware that the large costs involved in developing, procuring, and installing airborne equipment may be so high that airline management may decide that some of the recommendations cannot be implemented. However, the members of the Group are convinced that modern technology can meet the requirements of the airlines and other users. They feel obliged, therefore, as members of the airlines' operations community, to express what they honestly believe to be necessary if the aviation industry is to have any chance of achieving healthy and unrestrained growth. It may well be proven that, for economic reasons, such growth is beyond achievement, but much more knowledge and study than the Group is qualified to apply is needed before the economic aspects of the possible future systems can be properly assessed and management decisions reached. On the other hand, the ATCSPG believes that the consequences of continuing the policies of drift

that led to last summer's air-transportation debacle may be more unacceptable to the aviation industry than bearing its share of an acceptable ATC system.

In essence, the ATCSPG's recommendations represent a broad conceptual description of the air traffic management system it believes should be developed and implemented as soon as practicable. Every effort has been made to express what the members' experience in operating transport aircraft convinces them is needed, and at the same time to stay away from restricting system designers by suggesting details of how the objectives can be met.

CHAPTER FIVE

THE TRANSITION PERIOD

The ATCSPG's recommendations are intended to describe a totally new system of air traffic management, but the practical difficulties of introducing all the elements simultaneously are recognized well. For many reasons, the various features of the system should be introduced in a series of logical steps that give due regard to providing immediate benefits to the traveling public and the operators. It is particularly important that the measures required to improve system capacity be planned in a manner that enables ground and airborne subsystems to be introduced in a balanced and orderly fashion. Since the cost of the new or improved equipment and the cost of removing large and expensive jet aircraft from service to install it will be very high, it would be unreasonable to expect operators — whether airline, civil, or military — to undertake the expense unless there were known, tangible benefits to be derived. Consequently, not only must there be a *realistic* assessment of the expected advantages, including the effects on safety and economy, but ground subsystems must be operational in time to permit operators to take full and immediate advantage of the additional capability they have gone to the expense of installing. Furthermore, since planning modifications to a fleet of modern aircraft is an extremely difficult project, notice of ATC requirements involving airborne-equipment changes should be given as far in advance as possible.

An essential element in the introduction of a computerized control system is the availability of an automatic digital communications system. A firm recommendation to the FAA that planning details of such a system should be commenced immediately was made in March 1969, after approval by ATA's Operations Executive Committee. Because such a system will require international endorsement, almost certainly it will be several years before the ATC system will be able to use it. However, airline experiments with a system of automatic digital communications for operational-control purposes have already commenced and will provide valuable experience.

The greatest benefits to operators in the immediate future will be realized from airport-facility improvements that increase ground capacity and in improvements in navigation capability brought about by the introduction of area navigation. The latter improvement will be realized by the adoption of ATC procedures that take full advantage of the flexibility that the area-navigation concept offers in selecting and following non-conflicting flight paths in terminal areas and by fuel and other direct-operating-cost savings that result from taking more direct paths in the enroute phase. To implement area navigation (a) an airborne computer, (b) an appropriate display of geographical position in the cockpit for pilot orientation purposes, and (c) inputs from navigation sensors of adequate accuracy are all that are necessary. The current network of VORTAC facilities should be used for area navigation but it must be improved to the practical limits of its capabilities. It is desirable, for economic and practical reasons, that existing ground and

airborne equipment be used until and unless the need for an improved guidance system becomes apparent — i.e., when deficiencies in navigation systems prevent aircraft from being operated with the precision required to use airspace and airports efficiently.

The ATCSPG recommends that airline management give serious and urgent consideration to the development of an orderly plan for an economical and properly phased program of flight-deck design. Such a plan should be based on the probable necessity to use area-navigation routes and procedures in high-density areas in the near future. It should also facilitate the progressive incorporation in logical steps of all the improvements recommended for the airborne subsystem, starting from the relatively simple requirements for flying area-navigation routes to the sophisticated guidance-and-control system that the Group believes will become necessary in the years to come.

The FAA should use all modern forms of simulation, in both real and fast time, to ascertain how current practices can best be revised, without lowering safety standards, to (a) increase system capacity, (b) reduce dependence on radar vectoring, and (c) reduce route mileage flown by operators.

The hazard of mixed VFR and IFR traffic in marginal weather conditions in congested areas is cause for major concern. The recommended airspace restructuring was devised after very long discussion, during which every attempt was made to find a feasible means whereby aircraft of different performance and equipment standards could be separated, provided certain fundamental ATC requirements were met. The ATCSPG strongly urges that the FAA take immediate action on this very important issue.

The necessary procedures to utilize efficiently STOL and VTOL aircraft to obtain maximum benefit from their inherent advantages for certain purposes should be developed urgently.

The capabilities of airborne ATC transponders to assist ATC during the transition period should be exploited to the fullest extent. The identity, position, and altitude data they can provide is a major factor in improving today's manual ATC system.

Pending the implementation of the fully automatic ATC system, it is essential that energetic action be taken to effect all possible improvements in today's manual system. Recommended courses of action include the extended use of computers and digital communications, and providing better radar equipment, better displays, a better VORTAC system, visual airport surface guidance-and-control systems, and more flexible procedures.

Airport deficiencies must be corrected as rapidly as possible and difficult decisions on the positioning of new jetports where the need is urgent must be tackled with determination. STOL and VTOL ground facilities and reliever airports must be established as required. Current plans to implement improved automated visual runway and taxiway guidance systems should be pursued.

During the period of transition from the current ATC system to the recommended system, the following steps, which summarize the foregoing discussion, should be taken:

1. The new ATC system should be introduced in a series of logical and orderly steps that consider cost versus advantages to be derived by the users and the traveling public.

2. Implementation of the elements of the system must be well coordinated to assure maximum compliance; ample lead time must be provided to effect a well-planned installation program.
3. Operators who undertake the expense of installing improved airborne equipment must be assured that sufficient operational advantages can be derived from the additional capability.
4. FAA should begin immediate planning for digital communications as an essential step toward an automatic ATC system.
5. ATC rules and procedures must be modified to permit aircraft equipped with area navigation to take full advantage of this capability.
6. The current network of VORTAC facilities should be used for area navigation and must be improved to the practical limits of its capabilities.
7. Improvements in existing airborne VORTAC equipment must be made, within practical cost limitations, to achieve greater advantage of the system concept.
8. Desirable flight-deck modifications associated with new airborne navigation and automatic digital-communications concepts should be determined.
9. The FAA should use all forms of simulation in both real and fast time to ascertain how current practices can best be revised to increase system capacity and efficiency without lowering safety standards.
10. Immediate action should be taken to restructure the airspace to permit aircraft of different performance and equipment standards to be separated, provided certain fundamental ATC requirements are met.
11. ATC procedures should be developed to utilize efficiently the inherent advantages to STOL and VTOL aircraft.
12. STOL and VTOL ground facilities and reliever airports must be established as required.
13. The capabilities of current ATC transponders and automated features of the system should be fully developed to improve the ATC system.
14. Airport deficiencies must be corrected rapidly; aggressive action should be taken to locate sites for needed new airports and to build them.
15. Current plans to implement improved automated visual runway and taxiway guidance systems should be pursued.

In conclusion, it is essential that action be taken to effect all possible improvements in today's manual system, pending the implementation of the future automated system.

CHAPTER SIX

SYSTEM IMPLEMENTATION

If the potential value of this report is to be realized, the recommendations it contains must be translated into action without delay. Many of today's problems would have been solved long ago if the recommendations of previous reports had been fully implemented in a timely manner. For a satisfactory system to be implemented, the steps summarized in Figure 1 appear to be necessary. A possible detailed delineation of these steps is presented as Appendix D.

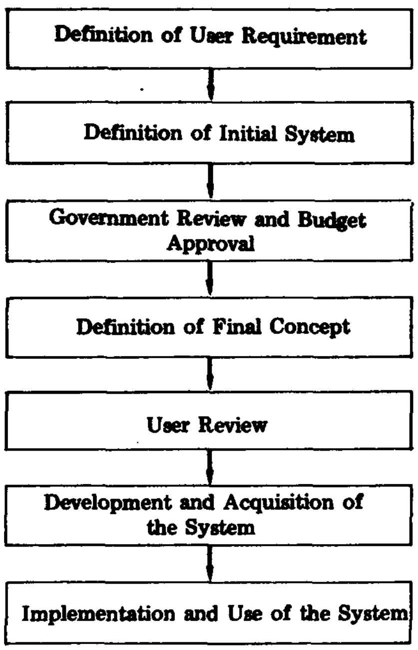

Figure 1. **ACQUISITION PROCESS FOR AN ATC SYSTEM**

This report, along with details of user requirements, will provide a basis for the initial definition of system requirements. Government review and subsequent budget approval will provide the backing necessary to start system development. A final definition of the system concept and subsequent user review will be required. Action can be taken then to begin the system development and acquisition process. System implementation is the final step leading to a functioning system. It is estimated that the process described, even if performed with maximum efficiency, would require ten years. It is therefore of paramount importance that all concerned pursue the program vigorously.

The ATCSPG recommends wide dissemination of this report to all the relevant sections of Government and industry. Because the responsibility for operation of the ATC system is by statute assigned to the Department of Transportation (specifically the Federal Aviation Administrator), Government agreement with the recommendations is essential if they are to be adopted, translated into workable plans, and implemented as funded programs that satisfy the requirements of all civil and military users of the system.

The ATCSPG recognizes that the Department of Transportation and the Federal Aviation Administration must take into account the legitimate needs of all users of the airspace. Consequently, conversations took place in April with the Aircraft Owners and Pilots Association, the National Business Aircraft Association, and the National Pilots Association. The result was a gratifying measure of broad agreement expressed in a joint statement by these general aviation organizations and ATA (see Appendix E). As already mentioned, representatives of the military users and the FAA participated directly in the Group's work and made many valuable contributions, which are included in this report.

The ATCSPG believes that the airlines, through the ATA, should seek prompt action at the highest levels of the Department of Transportation, the Federal Aviation Administration, and appropriate airport authorities to implement as soon as possible an Air Traffic Management system that complies with the recommendations contained in this report. A continuing process of monitoring by Government and industry will be necessary to insure that the objectives finally established are properly served during each step of the new ATC system's development — from the initial design stage through procurement, evaluation, and commissioning for operational service. Realistic time scales should be set and every effort made to insure that they are met by taking advantage of military experience in the development and implementation of systems of comparable magnitude.

APPENDIX A

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APPENDIX B

CHARTS CONCERNING AIR TRAFFIC GROWTH, OPERATIONAL DELAYS, AND FACILITIES FUNDING

38-681 O - 70 - 19

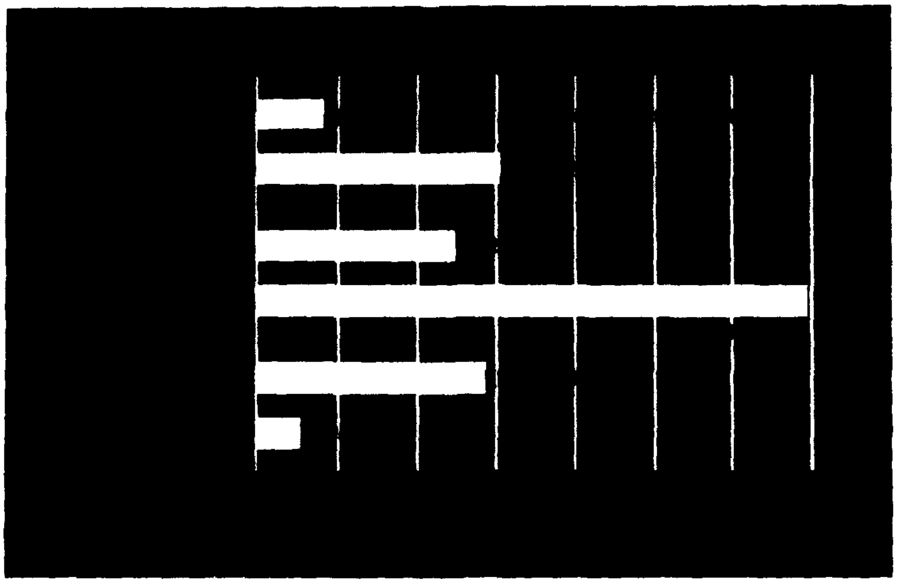

Figure B—1. **1968 DELAY COSTS (BY TYPE) OF MEMBER AIRLINE A**

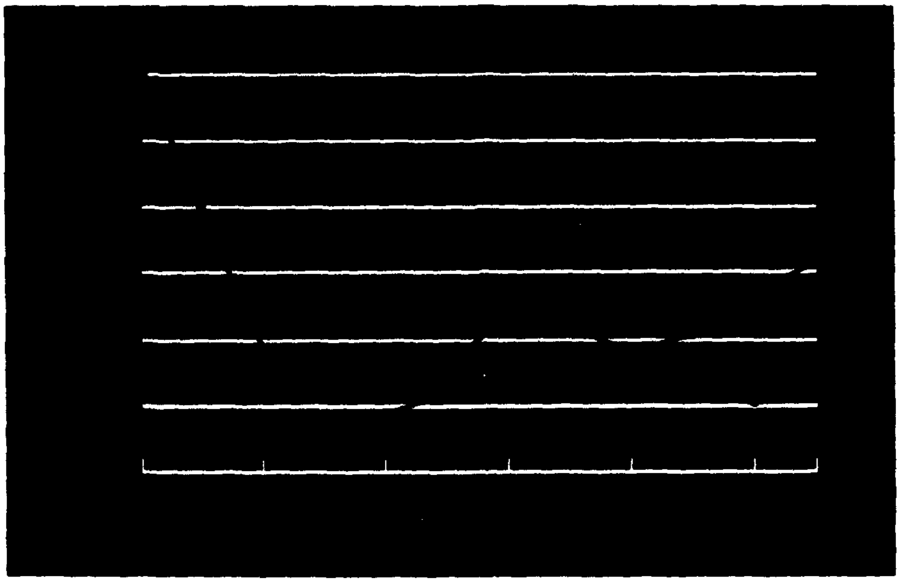

Figure B—2. **1968 DELAY COSTS (BY MONTH) OF MEMBER AIRLINE B**

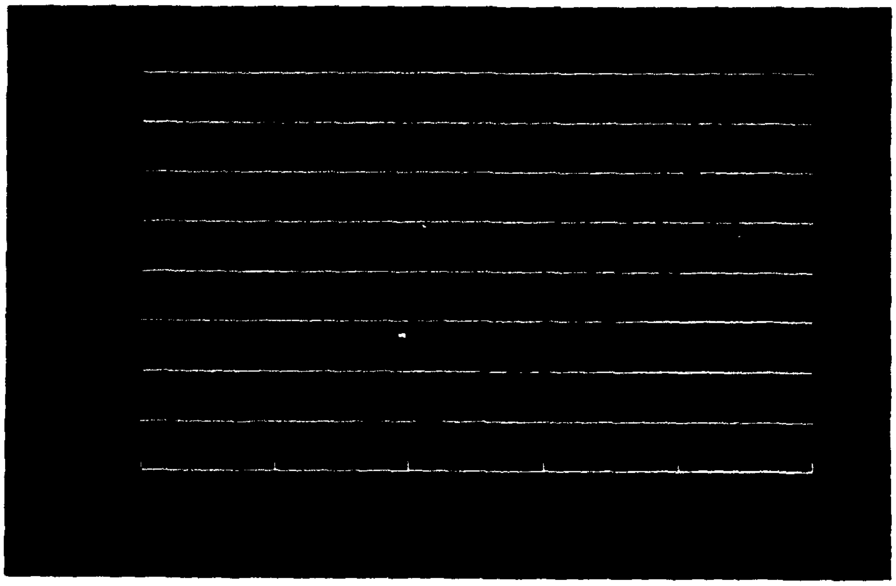

Figure B—3. **CHANGE IN SCHEDULED BLOCK-TO-BLOCK TIME**

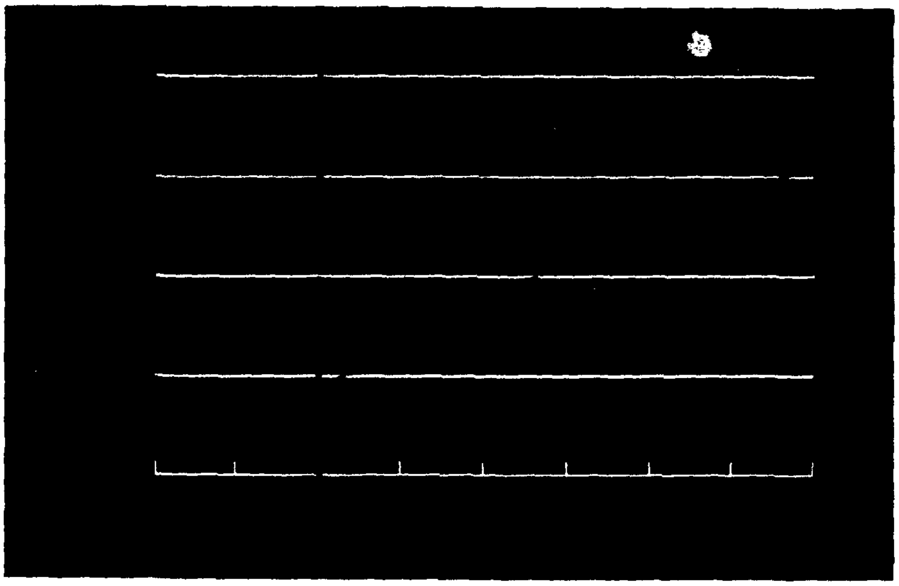

Figure B—4. **AIRCRAFT IN SERVICE — U.S. AIR CARRIERS**

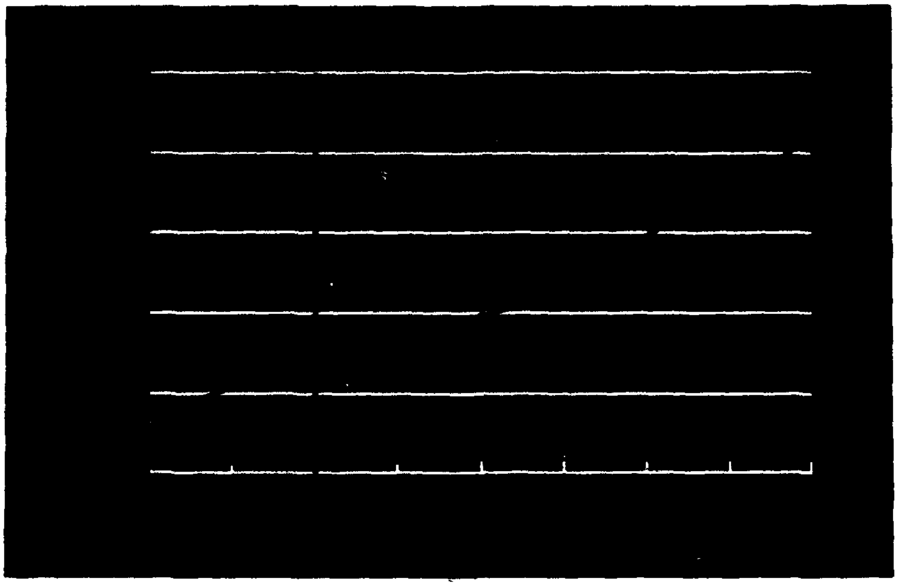

Figure B—5. **SCHEDULED-PASSENGER TRAFFIC — U.S. CERTIFICATED ROUTE AIR CARRIERS**

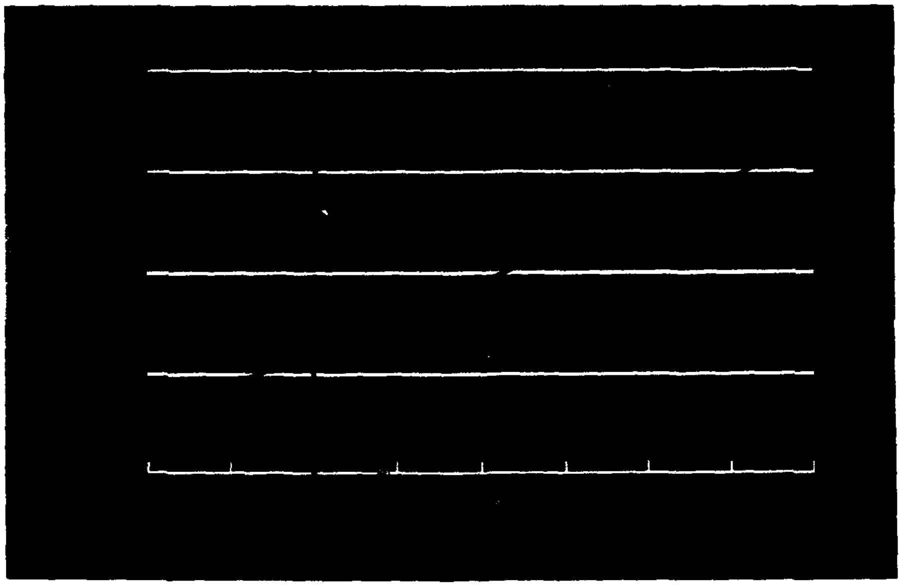

Figure B—6. **ACTIVE GENERAL-AVIATION AIRCRAFT**

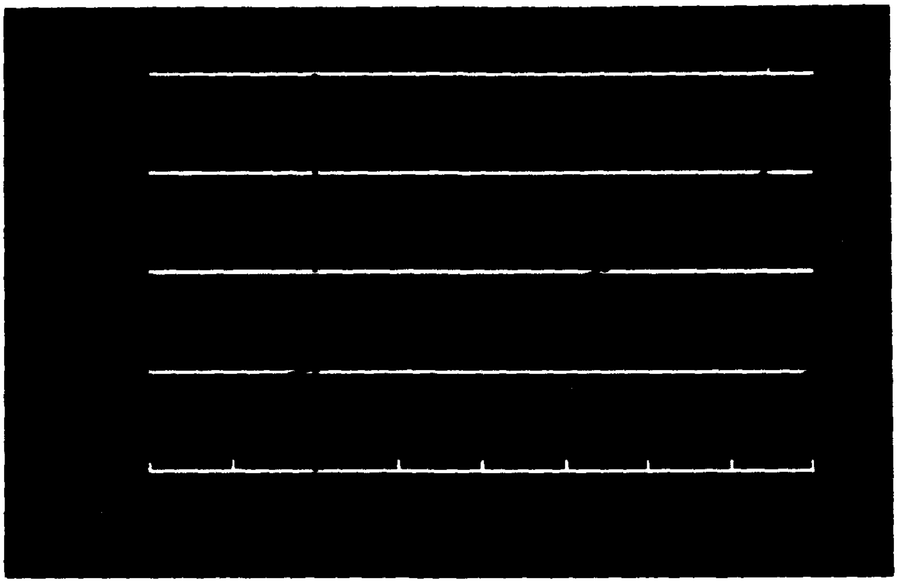

Figure B—7. **AIRCRAFT OPERATIONS AT AIRPORTS WITH FAA ATC SERVICE (Operations Include Those of Air Carriers, General Aviation and Military, Both Local and Itinerant)**

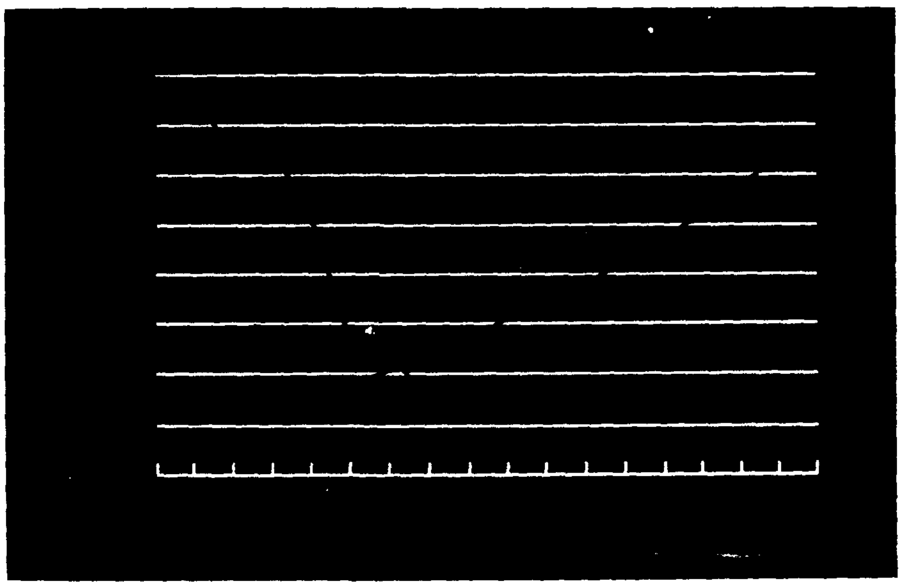

Figure B—8. **FAA FACILITIES AND EQUIPMENT FUNDING VS. AIRCRAFT OPERATIONS**

APPENDIX C

COMMUNICATIONS REQUIREMENTS FOR AIR TRAFFIC CONTROL*

INTRODUCTION

This appendix outlines an analytic process for defining the communications requirements for an Air Traffic Control (ATC) system. The process to be described entails the following major steps:

1. Concept Definition. Review the ATC concept and define its basic functions
2. Operational Analysis. Develop an operational concept for each basic function
3. Data-Transfer Requirements. Establish communications needs (internal and external) for each basic function
4. Engineering Analysis. Define alternate system conepts (hardware requirements) to meet the communications needs of the major functions
5. Cost/Effectiveness Trade Offs. Perform cost/effectiveness trade offs of the system concepts defined

The discussion that follows is made in the context of the basic Air Traffic Control concept that has emerged from the discussions of the ATA's Air Traffic Control System Planning Group. This concept comprises an aircraft equipped to navigate in three dimensions and to fly pre-established tracks with his position on such tracks made known to the ground ATC subsystem via a data-link. Such positive identification permits more extensive use of computers for the ground-control function of the ATC system. The concept is illustrated in Figure C–1, which notes the possible role of satellites in ATC communications.

The five steps in system definition and analysis are discussed in turn in the following sections.

CONCEPT DEFINITION

It is the objective of this step to translate the basic ATC concept into a series of functional areas for which operational responsibilities can be established. Figures C–2, 3, and 4 present gross functional definitions of the airborne, ground, and airline-interface subsystems, respectively. The figures represent preliminary analyses, and obviously require refinement. They are presented only to illustrate the analysis process and are not necessarily indicative of desirable configurations.

*This appendix is a summary of a discussion paper presented to the ATCSPG.

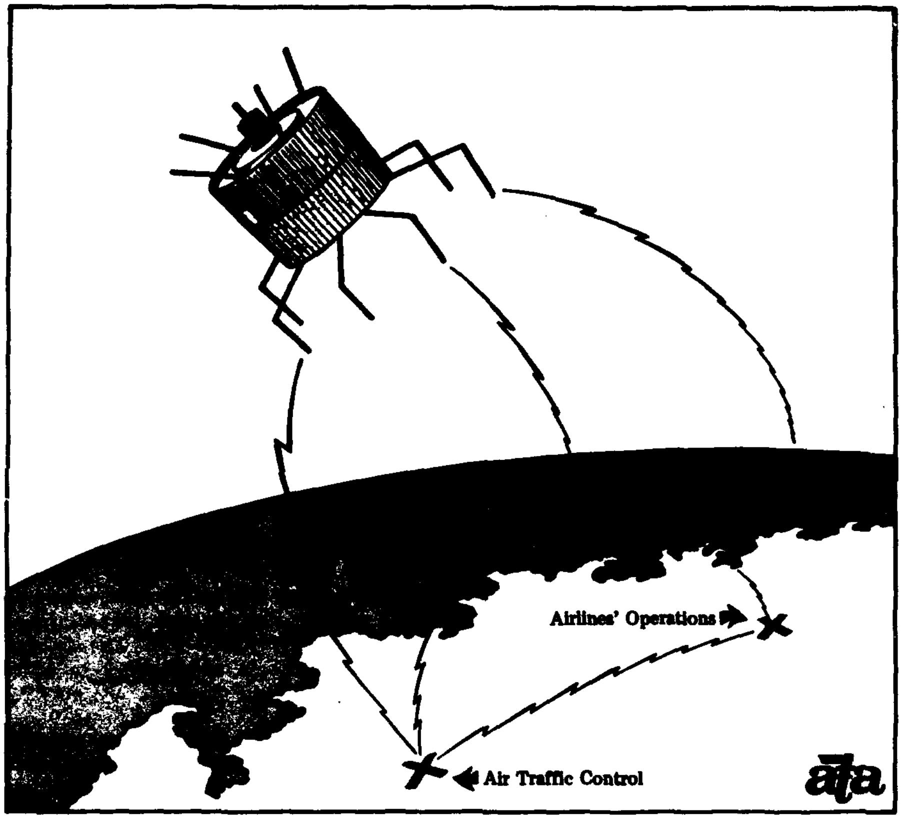

Figure C–1. **AIR TRAFFIC CONTROL COMMUNICATIONS LINKS**

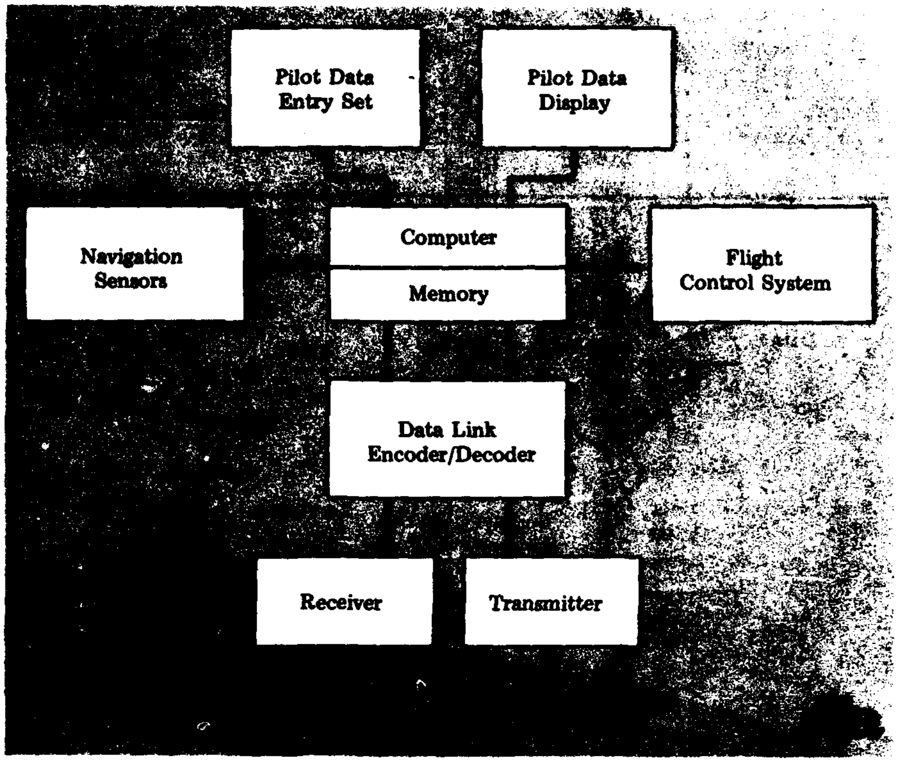

Figure C—2. **AIRBORNE SUBSYSTEM FOR AN ATC SYSTEM**

The keystone of the airborne subsystem, shown in Figure C—2, is the general-purpose computer. The computer accepts inputs from the navigation sensors to permit navigation in three dimensions; it can also provide steering information to the pilot or, assuming eventual FAA approval, direct inputs to the flight-control system. The computer can also format information for the data-link, which, in turn, will pass the position and identification information to the ground subsystem of the ATC system. Complementary items include the pilot's data display and a data-entry set.

Two major functions are identified for the ground subsystem, shown in Figure C—3. First, there is the executive-control computer that is charged with receiving flight plans, determining their acceptability, developing and maintaining flow-control procedures, and coordinating these requirements throughout the ATC system. With established tracks, the area-track computer function will come into play as the flight departs and progresses into its schedule. The area-track computer receives information from two sources: position information from the aircraft is received via the communications system's data-link and, simultaneously, the independent area-surveillance system receives duplicate information via

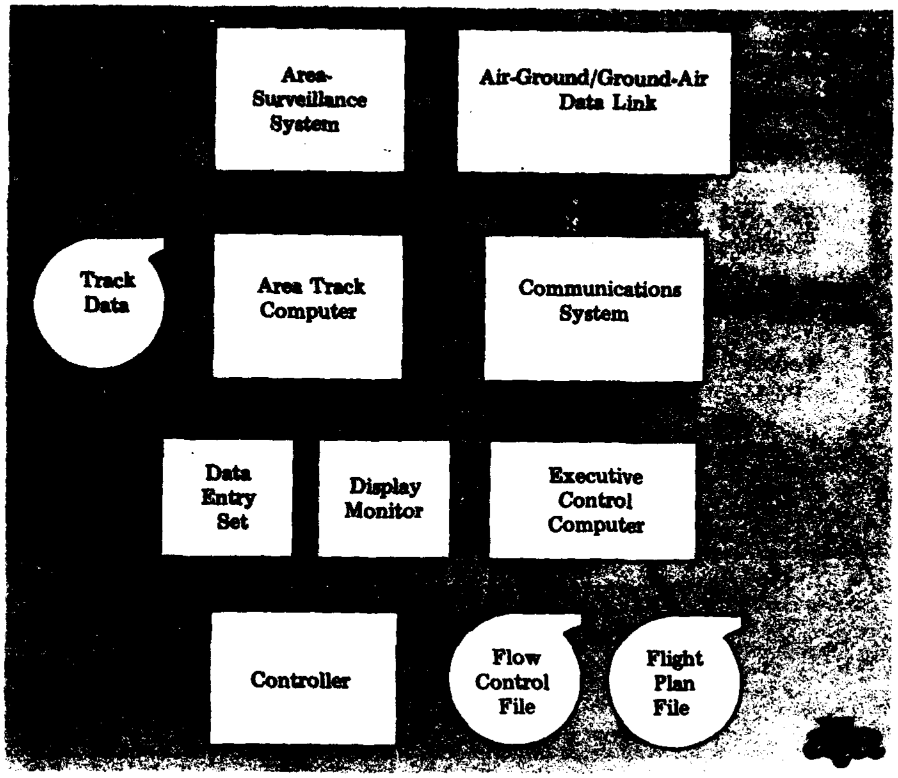

Figure C—3. **GROUND SUBSYSTEM FOR AN ATC SYSTEM**

other detection techniques and, after processing, inputs it to the computer. Validity checks are made by the computer by comparing the tracks for congruency. Then comparison of current position to pre-established tracks will be made. Also, computations concerning future cell occupancy will be made and possible conflicts determined. The track computer will issue appropriate instructions to correct deficiencies found in the tracks being followed, and to avoid conflicts with other aircraft. The human controller will monitor the system, interceding where required to insure that it operates in a smooth, efficient manner. The communications system will interface in turn, to other ATC units.

The third segment of the hypothesized ATC system (Figure C—4) is the airline-interface subsystem, which centers around the airline operations and the dispatcher. Again, a computer forms the heart of the subsystem. Its functions include flight planning, aircraft routing, and monitoring of in-flight progress. The data-link and the communications system tied to the operations computer provide a dynamic link that permits real time coordination between dispatcher and aircraft flow.

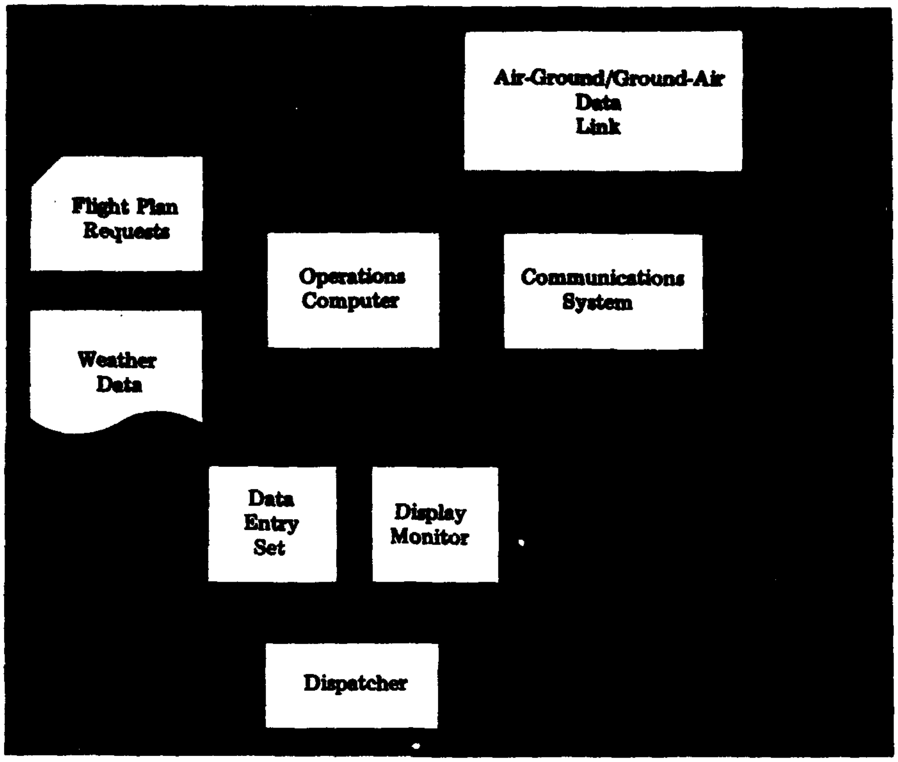

Figure C—4. AIRLINE INTERFACE SUBSYSTEM FOR AN ATC SYSTEM

OPERATIONAL ANALYSIS

Having established a functional system that satisfies the ATC concept, the analyst can now study the operational sequence as a prelude to identifying data requirements. Figure C—5 presents an example of an operations analysis for the area-track function of the ground subsystem. The analysis begins with the recognition of a flight plan, which is entered into the computer as a track profile according to which an aircraft must be at a given point in space at a given time. The operational analysis proceeds by identifying each function that must be performed and showing actions that must be taken in the event of a given situation. An analysis such as this must be performed for each major function of the ATC system.

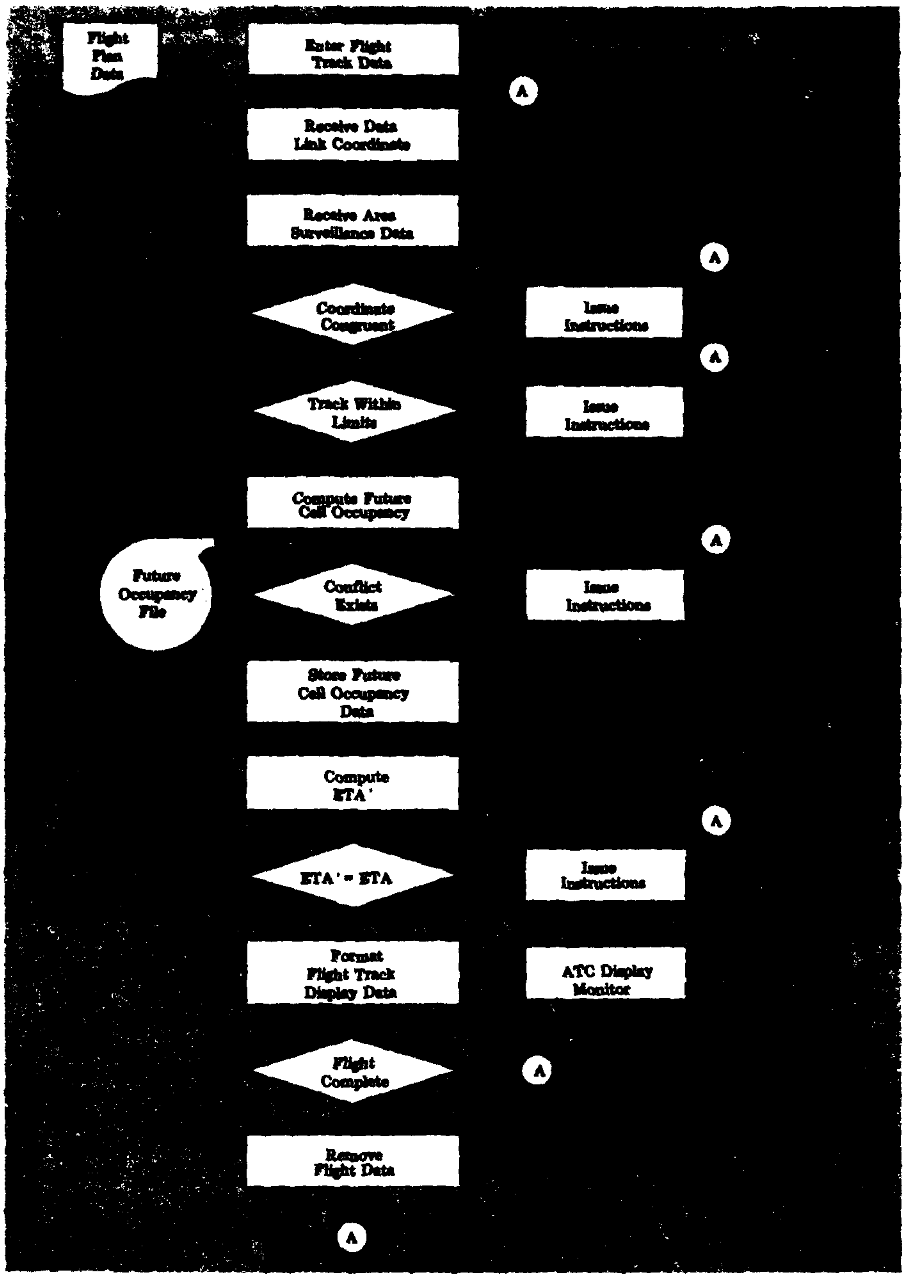

Figure C–5. **OPERATIONAL ANALYSIS OF THE TRACKING FUNCTION**

DATA-TRANSFER REQUIREMENTS

For the system to perform the various functions defined in the operations analysis it must have certain information. Table C—1 shows an analysis of the requirements for the area-track function; data to be developed in the aircraft and transmitted by the data-link are listed along with columns for subsequent insertion of the required frequency of transmission (see below). These data would provide for position reporting, track change, track-change authorization, track-change execute, track clearance, etc., which are considered to be basic parameters.

Another part of this task is the identification of the number of bits associated with each parameter. The accuracy and granularity to be associated with each parameter, and the frequency (number of repetitions per unit of time) at which each is transmitted must be established. The frequency of repetition will depend on the aircraft's location in the flight profile — departing, enroute, or on final approach. A further input to the data-transfer requirements will be the number of aircraft being controlled; inputs from traffic-density projections would provide useable estimates for this input.

ENGINEERING ANALYSIS

With a functional definition, and the data-transfer requirements established, analysis now turns to the engineering implications of the system.

Translation of communications requirements into system specifications requires a thorough engineering analysis. For an ATC system this is particularly true, since accuracy and timeliness of the data transfer is mandatory. In this section some of the problems associated with providing an ATC digital data-link between the ground and an aircraft either on the ground or in flight are discussed very briefly. First, two modes of communication are considered: direct link and satellite-relay link. This is followed by subsections concerning signal-to-noise margins, modulation methods, digital techniques, and circuit demand.

Direct Link

At VHF and UHF frequencies there is little refraction and diffraction of radio energy and, consequently, reliable communications are bounded quite sharply by line-of-sight considerations. Thus, extended ranges are possible only at the higher altitudes and, unfortunately, even the highest aircraft altitudes do not afford very great ranges, as evidenced by the following table:

Altitude (Feet)	Ground Radio Range (Miles)
10K	123
20K	173
30K	212
40K	248
50K	276
60K	300

Table C—1. **DATA-TRANSFER REQUIREMENTS FOR THE AREA TRACK FUNCTION**

Data Element	Data-Link Direction	Frequency of Transmission (Repetitions per Minute)		
		Depart	Enroute	Approach
Position	Air-Ground			
Identification Code				
Track Number				
Latitude				
Longitude				
Altitude				
Latitude Rate				
Longitude Rate				
Altitude Rate				
Time				
Track-Change Request	Air-Ground, Ground-Air			
Identification Code				
Track Number				
Depart Longitude				
Depart Latitude				
Depart Altitude				
Depart Time				
Way Point No. Latitude				
Way Point No. Longitude				
Way Point No. Altitude				
Way Point No. Time				
Entry Way Point Latitude				
Entry Way Point Longitude				
Entry Way Point Altitude				
Entry Way Point Time				
Change Priority				
Track-Change Authorization	Air-Ground			
Identification Code				
Track No.				
Authorization Code				
(Repeat Change Data)				
Track-Change Execute	Air-Ground			
Identification Code				
Track No.				
Authorized Code				
Execute Code				
(Repeat Change Data)				
Track-Clearance	Ground-Air			
Identification Code				
Track No.				
Clearance Ahead				
Clearance Behind				
Clearance Above				
Clearance Below				
Clearance Right				
Clearance Left				
Track Time				
Time Difference				

Some increases in the above ranges can be caused by ray bending and the location of the ground antenna at a non-zero height; on the other hand, coverage shadows can be created by hilly terrain surrounding the antenna. In any case, the maximum range for reliable communications will be approximately 250 miles. Thus, the relatively short range (compared to that of a satellite-relay link) and the low path losses involved allow the use of simpler — and therefore less expensive — airborne and ground terminals.

Since sustained maneuvers at large roll and pitch angles are unusual during commercial operations, lower hemispherical antenna coverage will probably be sufficient for the aircraft, and average antenna gains on the order of 3 dB are likely. The ground terminal would require upper hemispherical coverage and should also exhibit an average antenna gain of approximately 3 dB.

Digital communications are more sensitive to multipath problems than are voice communications, and this problem must be considered, even for a direct link. The problem will be discussed in connection with satellite-relay links, since it is of greater magnitude there.

Satellite-Relay Link

Currently, synchronous satellites dominate the planning of satellite-relay links. Their prime advantage lies in the fact that three symmetrically-placed satellites can provide complete global illumination, except for two small, approximately triangular regions at the poles. Their use, however, involves two major transmission disadvantages: path loss and multipath.

Path Loss

The synchronous satellites are at an altitude of 22,000 miles above the surface of the earth and the longest ground/satellite path involved is about 26,000 miles. The large path losses implicit in radio transmission over such distances must be compensated for in the characteristics of the transmitters, receivers, and antennas.

A half-beam width of approximately 20° is required for a satellite to illuminate the surface of the earth and no more; this implies a theoretical satellite antenna gain of 22 dB. The airborne antenna would of necessity have upper hemispherical coverage with a gain of 3 dB. The satellite/ground link is considerably less critical, since the fixed position of the satellite relative to the ground station allows use of a highly directional and, consequently, high gain antenna; furthermore, high-power transmitters and low-noise receivers can be justified economically at the relatively few ground terminals required.

Multipath

Multipath problems are caused by energy's traveling from the transmitting antenna to the receiving antenna by diverse paths. Direct energy will travel in a straight line between the transmitting and receiving antennas, while interfering — or reflected — energy will make the transit via a bounce off the earth's surface. In linearly polarized systems, interference is constructive or destructive depending on whether the phase difference between the direct and reflected waves is an even or odd number of half cycles. The phase difference is determined by the phase of the reflection coefficient and the length of the reflected wave's path. When the direct and reflected waves are completely out of phase (destructive interference), the net signal amplitude at the receiver is decreased in proportion to the the magnitude of the reflection coefficient, which is never greater than 1.

Under multipath conditions, use of circularly polarized transmitting and receiving antennas is significantly beneficial to communications over the entire range of look angles. Other methods of combating multipath problems are based on the fact that if two communications channels fade independently and with the same probability [P_f = 0.01], the probability of the two fading simultaneously is 0.0001. Independent fading of the two (or more) channels — the essential characteristic of these methods — can be achieved by several techniques: space diversity, time diversity, frequency diversity, angle diversity, polarization diversity, and rake. Each of these techniques delivers the desired signal to the receiver on two or more channels; the receiver then selects, from moment to moment, the channel that is delivering the strongest signal.

Signal-to-Noise

Assuming a noise figure of 3 dB for the aircraft receiver, a noise bandwidth of 15 kHz (corresponding roughly to a 25-kHz channel spacing), and a required signal-to-noise ratio (including margins) of 40 dB, the required power level at the receiver is -137 dBW, which requires the following transmitted powers:

Frequency	Power Requirement	
	From Satellite	From Ground
100 MHz	23 dB = 200 W	2 dB = 1.6 W
1 GHz	43 dB = 20,000 W	22 dB = 160 W

These calculations are equivalent to determing the transmitted power required to provide a 10-μV signal to the receiver input.

Modulation Methods

In the case of the down-link from a synchronous satellite to an aircraft, the transmitter power required — as listed in the above table — is awkwardly large, especially because the power listed is that required for one channel, not for the total satellite. This requirement was based on simple binary on-off keying (OOK) which, like the analogous amplitude modulation (AM), is simple to implement but relatively inefficient. Consequently, the optimal system will probably use a more sophisticated modulation technique: it makes economic sense to trade off increased end-equipment complexity and bandwidth against a reduction in the required transmitter power. Possible modulation methods are binary frequency shift keying (FSK) and phase shift keying (PSK). Completely coherent detection is possible with both these methods, but its advantages probably do not justify the cost of the complex equipment required. For the ATC communications system, incoherent detection with FSK or a method referred to as differentially-coherent phase shift keying (DPSK) would probably be suitable. The latter method has been used very successfully in the Collins "Kineplex" HF data-communications system.

Digital Techniques

Due to the requirement for data accuracy in air traffic control, the choice of the data transmission format is critical. Items to be considered include:

- Word structure
- Language (BCD, BNR)
- Parity checking
- Transmission order
- Logic levels
- Synchronization
- Error detection
- Redundancy

Some form of error detection, such as parity checking or gray code, is essential. More sophisticated techniques are available but the choice must depend on a trade off between cost and performance — maintenance of safety, of course, represents one of the limits in this trade off. Considerable work in this area has been done by RTCA and AEEC, but further study of the subject, as it relates specifically to the ATC system, is recommended.

Circuit Demands

A final engineering area to be considered is that of circuit loading and the determination of required channel capacities. The judgements to be made include:

- Should ATC data-link channels be dedicated solely to ATC or should they share with other functions?
- Should aircraft be called selectively to report position or should they report randomly?
- How many channels will be needed to meet immediate needs; how many to accomodate system growth?

These questions can be answered by use of operations research models; the characteristics of the system can be introduced and the consequence of a particular choice determined. For example, the problem of multiple random channel users can be readily examined. The probability (P) of no overlap for n signals (from n aircraft) within a period T with each signal having a duration, k, is equal to the following:

$$P = \left[1 - \frac{(n-1)k}{T}\right]^{n} \frac{(T-k)^{n-1}\left[T+(n-1)k\right] - \left[(n-1)k\right]^{n-1}\left[nT-(n-1)^{2}k\right]}{T^{n} - \left[(n-1)k\right]^{n-1}\left[nT-(n-1)^{2}k\right]}$$

Thus, with knowledge of the number of aircraft expected to be operating on the same frequency in a common reception area, the likelihood of interference (overlap) of transmitted data can be predicted. Alternate schemes, such as sequential polling, may be evaluated to determine channel loading, and ultimately to establish channel requirements.

COST/EFFECTIVENESS TRADE OFFS

The foregoing sections have described the process by which a concept for ATC communications is translated into functional elements. These functional elements are in turn interpreted in an engineering sense and hardware requirements are established. With the establishment of the hardware requirements, it is possible to investigate the cost/effectiveness aspects. This process requires that each hardware element be subjected to a cost analysis. Additionally, it should be established that the current technical state of the art will support the technical requirements defined. A further part of this analysis entails relating the defined hardware to the existing system and establishing what evolutionary process would be necessary to make the transition from what now exists to what is described. Following this, the system reliability that is inherent in the established concept should be determined. With these factors in clear focus, it is possible to exercise judgements concerning the proposed system. It is quite possible that revisions will be required to the original concept based on findings established through the cost/effectiveness analysis outlined here.

The cost/effectiveness analysis coupled with the functional, operational, and engineering analyses described in previous sections represents system architecture. The ten major activities diagrammed in Figure C–6 comprise a typical system-architecture program. The first six are of specific interest to this discussion and may be summarized as follows:

1. Define the client's technical requirements and resource constraints
2. Hypothesize feasible system configurations that may satisfy the requirements and constraints
3. Perform effectiveness analyses of the hypothesized configurations to identify those that can meet the requirements
4. Perform cost analyses of the hypothesized configurations to identify those that can meet the requirements.
5. Select the optimum configuration by performing cost/effectiveness analyses
6. Prepare system specifications based on the optimum configuration

The effectiveness of a system is a quantitative measure of its ability to satisfy a set of requirements. It is a function of three major system attributes: availability, dependability, and capability. Quantification of system effectiveness according to this framework provides one of the three inputs to cost/effectiveness analysis. The second input, of course, is cost and the third is leverage effects, which may be characterized as indirect advantage or disadvantages of the system that are not formally covered in the requirements-and-constraints dossier: good expansion capabilities, for example, might provide positive leverage in the form of potential future savings.

A system's availability and dependability are functions of its reliability and maintainability. Complexity, quality of material, quality of workmanship, and degree of redundancy in the design are the major influences on reliability. Maintainability is a measure of the facility (speed) with which the system can be restored to service after a failure; design features and the extent of operation-monitoring provisions are the major influencing factors. Capability is a measure of how well the system performs in terms of data ratios, range, system flexibility, etc.

The cost/effectiveness analysis of the proposed communications system not only provides guidance towards obtaining the most cost-effective system, but also provides valuable inputs to justifying the system to airline managements and the Government agencies involved. Accordingly, the importance of this step cannot be over-emphasized.

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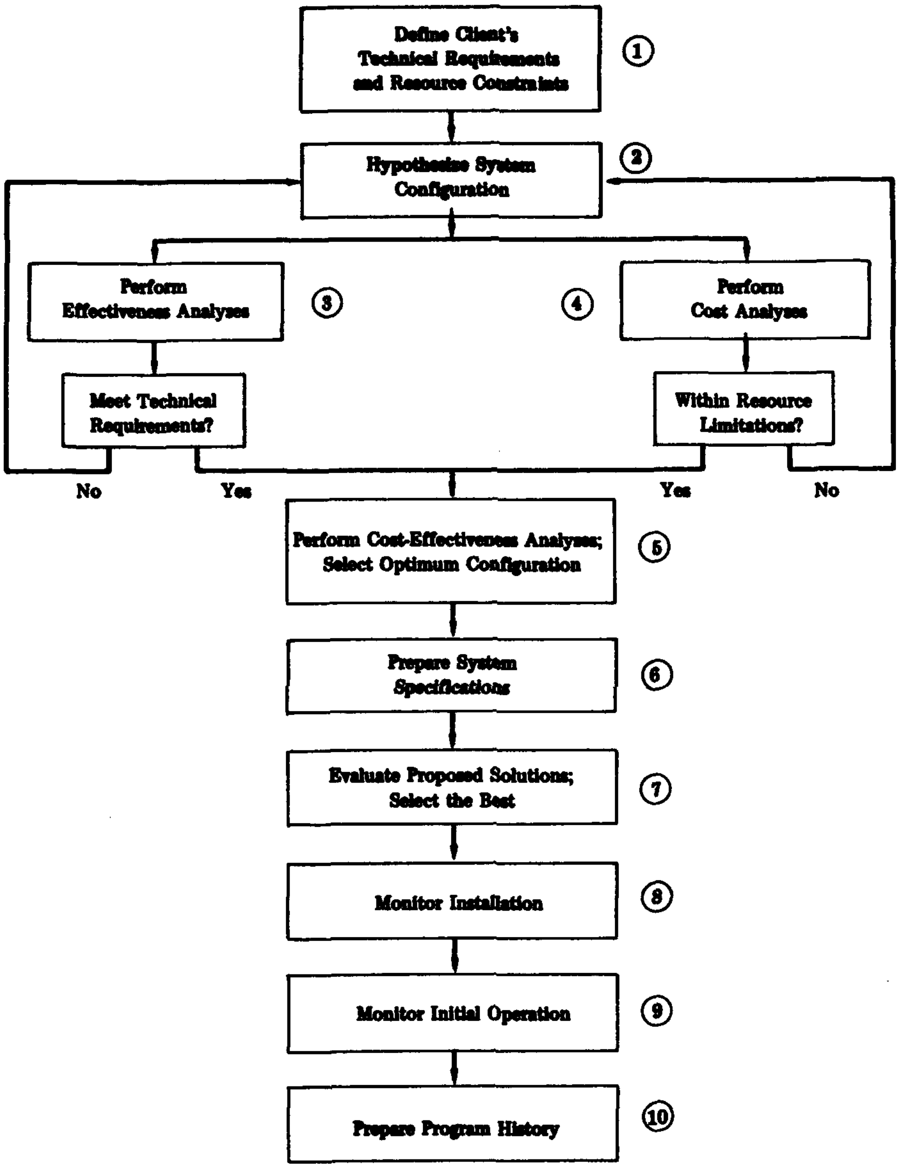
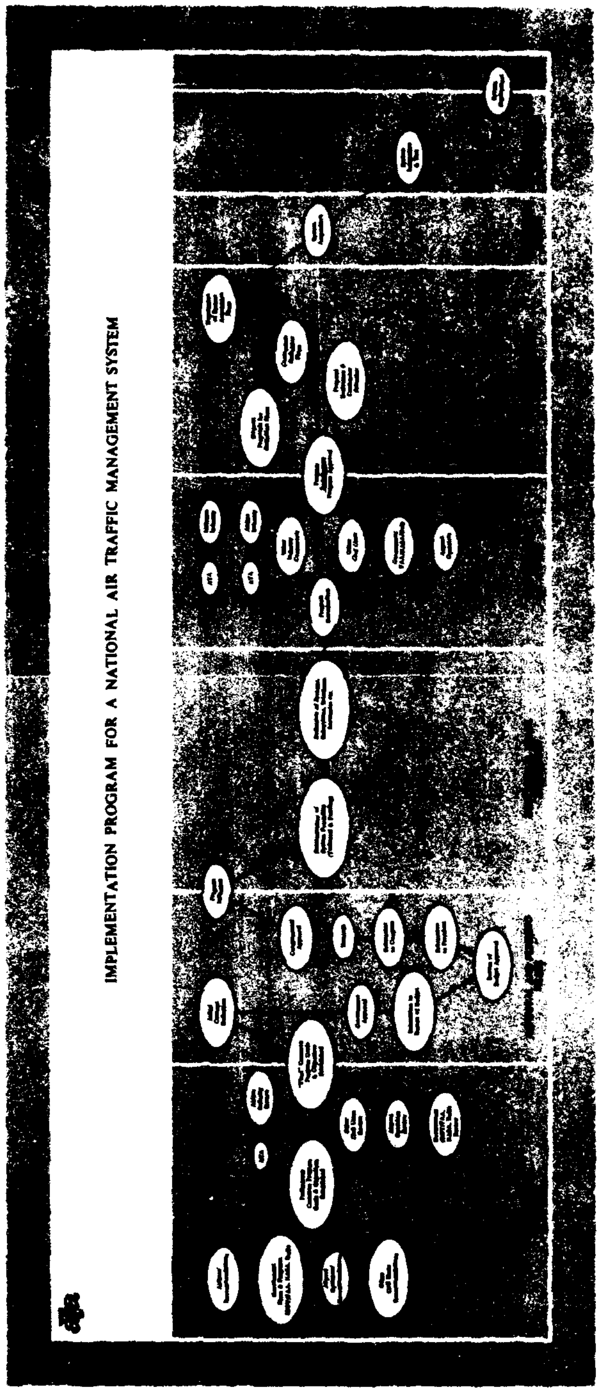


Figure C—6. **ACTIVITIES OF A TYPICAL SYSTEM-ARCHITECTURE PROGRAM**

APPENDIX D

IMPLEMENTATION PROGRAM FOR A NATIONAL AIR TRAFFIC MANAGEMENT SYSTEM


IMPLEMENTATION PROGRAM FOR A NATIONAL AIR TRAFFIC MANAGEMENT SYSTEM

APPENDIX E

JOINT STATEMENT BY USERS OF CIVIL AIRCRAFT

May 9, 1969

The Honorable John A. Volpe
Secretary
Department of Transportation
800 Independence Avenue, S. W.
Washington, D. C. 20590

The Honorable John H. Shaffer
Administrator
Federal Aviation Administration
800 Independence Avenue, S. W.
Washington, D. C. 20590

Gentlemen:

On April 10, 1969, a joint meeting was held between the Air Transport Association, Aircraft Owners and Pilots Association, National Business Aircraft Association and the National Pilots Association for the purpose of exchanging views on broad principles for the future design of the Air Traffic Control System. During the discussions it became apparent that there was considerable agreement among the attendees on certain basic philosophies and concepts that should govern planning for the ATC system of the future. A desire was expressed to communicate these common thoughts to those responsible in the form of a joint statement. Accordingly, on behalf of their associations, the undersigned are transmitting to you the attached, mutually agreed upon, statement of "broad principles on which planning for an efficient national system of air traffic management should be based."

We respectfully ask that you and your staffs give due consideration to these principles as you plan ATC improvements.

Sincerely,

Clifton F. von Kann
Vice President
Operations & Engineering
Air Transport Association

Victor J. Kayne
Vice President
Policy and Technical Planning
Aircraft Owners and Pilots Association

William H. Ottley
Executive Director
National Pilots Association

Robert B. Ward
Executive Vice President
National Business Aircraft Association

Attachment: Joint Statement

Attachment to Letter dated May 9, 1969

JOINT STATEMENT

"The civil aircraft airspace users, represented by AOPA, ATA, NBAA, and NPA are unanimously agreed that planning an efficient national system of air traffic management, which includes airports, ATC, flight regulations and procedures, should be based on the following broad principles:

1. Widely divergent aircraft performance characteristics must be taken into account in applying airspace utilization techniques and procedures. The different capabilities and requirements of the various segments of civil and military aviation must be accommodated to the maximum practicable extent, so that all can coexist harmoniously and continue their natural growth in the country's economic interests.

2. Airports should provide separate runways and associated facilities that meet the differing requirements of the users by making efficient use of valuable real estate to insure maximum runway availability for all users.

3. The advantages of automation, both on the ground and in the air, must be fully exploited to allow air traffic to expand safely, pilot and controller workload to be eased, and keep the cost of operating the ATC system to the minimum.

4. Expanded airborne navigation capability is essential to increase efficiency by enabling pilots to follow in certain controlled airspace of the future, predetermined flight paths with the precision necessary for reduced safe separation without the need for radar services. The responsibility for navigation should always rest with the pilot. The ATC responsibility for a safe and expeditious flow of traffic should be based on accurate and reliable

position information obtained directly, and preferably automatically, either from the aircraft or from an overall system of position determination. The potentialities of airborne station keeping devices should be fully explored.

5. Automatic digital communications must be implemented as soon as possible to relieve the load on voice communications and to facilitate the introduction of on line data processing equipment in the ATC system. The voice system must be retained.

6. The civil aviation organizations endorsing this statement of broad policy offer the Federal Government and the airport authorities their full cooperation in attaining the objectives outlined."

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GLOSSARY

Airborne Guidance and Control System — An integrated aircraft navigation system that permits following any three-dimensional path desired. As used in this report, no specific sensory input is intended.

Aircraft — Any device that is used or intended to be used for flight in the air.

ARTS — **Automated Radar Terminal System** — A currently planned ATC system for terminal areas using computer technology and radar.

ATC — **Air Traffic Control** — A service operated by appropriate authority to promote the safe, orderly, and expeditious flow of air traffic.

Air Traffic — Aircraft operating in the air or on an airport surface, exclusive of loading ramps and parking areas, but including aircraft departing from or arriving at such areas.

Air Traffic Controller — A duly authorized individual involved in providing ATC service.

Air Traffic Control System — All components, human and physical, of a system providing ATC service.

Air Traffic Management System — As used in this report, the complete system used in air traffic, which includes ATC, rules and regulations, the necessary airports and other landing and take-off facilities.

Area Navigation — A method of navigation that permits aircraft operations on any desired course within the coverage of station-referenced navigation signals or within the limits of self-contained system capability.

Automatic Digital Communications System — A system for exchange of communications in a form suitable for direct input to or output from printers, display devices, computers, data processors, etc. When the word "automatic" is used, it generally implies that machines either generate or utilize the communications without the necessity of human intervention.

CAS — **Collision Avoidance System** — A device installed on aircraft for the following purposes:

: Detecting the presence of other aircraft

: Automatically assessing the potential collision hazard represented by such other aircraft.

: Providing advance warning to the pilot if a threat is predicted by the equipment.

: Providing appropriate command signals indicating the proper evasive maneuver.

The CAS device performs its functions continuously and automatically in all types of weather conditions without requiring visual assessment of collision risk by the pilot.

Clearance — An authorization for an aircraft to proceed under specified traffic conditions within controlled airspace; given by ATC for the purpose of preventing collision between known aircraft.

CTOL — Conventional Takeoff and Landing — Designation of aircraft that have conventional performance with respect to runway needs and climb/descent angles.

FAA — Federal Aviation Administration — The U. S. Government agency responsible for ATC and for supervising civil aviation activities from a safety point of view.

FAR — Federal Aviation Regulations — Regulations published by the FAA to assist in carrying out its assigned functions.

Flight Path — The combination of an altitude profile with a horizontal track.

IFR — Instrument Flight Rules — Rules governing the operation of aircraft when weather conditions are poorer than those specified for visual flight rules.

NAS Stage A — National Airspace System Stage A — A program for improved use of radar and computer technology in the enroute airspace of the U. S.

Operational Control — With respect to a flight, means the exercise of authority over initiating, conducting, or terminating a flight.

PWI — Proximity Warning Indicator — A device on an aircraft that automatically alerts the pilot to the presence of another aircraft but leaves to the pilot the task of visually sighting the intruding traffic, assessing the collision threat posed by that traffic, and determining what, if any, evasive action is needed. Because of the need for visual sighting of traffic, proximity warning devices can be effective only when there is adequate in-flight visibility.

STOL — Short Takeoff and Landing — Designation of aircraft that have performance characteristics requiring shorter runways than CTOL aircraft. STOL aircraft generally may also employ steeper angles of climb and descent than CTOL aircraft.

VFR — Visual Flight Rules — Special rules for conducting flight with the responsibility for collision avoidance resting with the pilot. These rules apply only when the weather is at or above the weather minima specified for such flight.

VORTAC — Collocated VOR and TACAN.

VTOL — Vertical Takeoff and Landing — Designation for aircraft that have performance characteristics permitting vertical or almost vertical takeoffs, landings, and climb and descent angles.

General VON KANN. Both the Department of Transportation and the Air Transport Association projects establish R. & D. objectives for the ATC system. The main need will be for highly skilled management and systems engineering.

With airports there is less cause for optimism, mainly because it will be all but impossible to build by 1980 any new airports suitable for air carrier operations whose site has not already been selected and approved. It is frightening but true that no more than a very few new airports of this type will appear in the United States during the next 10 years.

So while the anticipated user charge legislation may facilitate airport financing, these funds will have to be used mainly to improve existing airports—actually to stretch existing capacity as far as it will go and thus to delay the evil day when the airport becomes the ultimate bottleneck in the system.

With the jurisdictional problems involved in programing these improvements, and the pressures of noise abatement measures to reduce airport acceptance rates, it is impossible to foresee adequate capacity at the major airline airports in the coming decade.

Mr. HECHLER. Isn't it already?

General VON KANN. At some locations, yes, sir. On that one, we run into great discussion on whether or not the bottleneck is the ATC system or the airport, and you can argue it both ways, and as a matter of fact we have not really established systems for measuring the effectiveness of either.

The FAA has recently undertaken a project to attempt to allow itself to better measure its systems effectiveness with respect to the airways. This should be done. I think that sometimes the runway is the bottleneck, the runway acceptance rates.

At the other hand there is some periods where the runway isn't too busy but the ATC system doesn't deliver the planes in as fast as the runway could take them. I think it shifts back and forth. But I see more hope for solving the problems in the air than the ones on the ground, in the coming decade.

Mr. HECHLER. I don't want to interrupt your testimony with argumentative items, but you have certain size planes that can't land on certain size runways, and this is why I made the observation that sometimes the airport is the real bottleneck.

General VON KANN. Oh, it is at times, and I will come back to this point as I proceed.

Mr. GOLDWATER. Mr. Chairman, could I ask a question?

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. Improving existing airports from your statement; do you feel that perhaps even if we did this, it still wouldn't be enough or wouldn't be adequate, primarily because of the limitations that have been created around airports today? In other words, in creating, in improving what we already have, would seem to me that in many instances, the airports we already have, especially on large municipal airports, they have been improved almost to capacity now.

And if in fact this is true, what is the alternative? Build new airports?

General VON KANN. Well, I will come to that as I proceed. It is true that a great deal of money has been put into airport improvement. On the other hand, you can take Kennedy Airport and there are proposals for further construction, backing the northeast-southwest runways into the bay, which would improve the capacity still further.

For one reason, it would cut down on the noise impact on the community. On the other hand, there is great opposition even to this. In Boston at Logan, other runways could be added, again the local community are violently against it. So there are things that could be done. There are things that will have to be done at existing airports.

But I don't think it will be enough, and it comes with great difficulty. As a matter of fact, you take both the Boston and New York situation. If you talk about improving the current facilities, then you can't talk about an additional airport, and if you talk about an additional airport, you can't talk about improving the current facilities.

And you constantly have got this sort of a conflict at work. We will come back to it.

Chairman MILLER. Mr. Chairman.

Mr. HECHLER. Mr. Chairman.

Chairman MILLER. I have to leave in a few minutes, but I am very vitally concerned with this problem. Has the Air Transport Association ever studied the optimum type of airport and buildings that should be at an airport?

General VON KANN. I don't think anyone has studied that, Mr. Chairman.

Chairman MILLER. Then as the representative of the airlines, why haven't you studied it?

General VON KANN. Well, as far as——

Chairman MILLER. You know that this is the biggest mess in the world. Now, as one who uses the airplanes a great deal, I frequently go to Los Angeles. If I take one line to Los Angeles, I can ride a thousand feet on a movable airport sidewalk. If I take another line I have to walk a thousand feet. If I come into San Francisco on one major airline, and I want to take another airline out, I have got to walk nearly half a mile.

Now, one can lose more time getting around the airports than in getting across the country. Now, why hasn't an organization such as yours, given some thought to this and tried to influence a standardization, one that will serve the public in the air industry?

General VON KANN. Well, I can answer that, sir, in about three ways. First of all, we are doing a great deal along that line.

Chairman MILLER. I say you haven't done anything in the last 10 years, anyway, except Dulles.

General VON KANN. Well, we can't take credit for that. By the way, most airport development is done at the local level for one thing.

Chairman MILLER. That is one of the things. I think, and without anticipating your answers, this is the very evident fact. Each city builds its own airport, gets its own architect and each is going to outdo the other, without giving much thought to the convenience of the traveler.

And I think some organization should have at least represented the traveler in this matter. I would imagine that you would have done this, because most other means of transportation over the years have

tried to fix up their stations and unify them so you know where you are going and what you are doing.

General VON KANN. Well, there is a greatly expanded effort in our association, sir, and there has been for the last 3 years. As a matter of fact, 3 years ago we organized a new airport facilities department, which is aimed in this direction.

But I must also say this is not an easy operation, because anybody attempting to put standardization into a system like this comes in conflict with all the local jurisdictional interests.

Chairman MILLER. I appreciate that.

General VON KANN. So more should be done, and the kind of study that you indicated when you raised the question was also suggested by the transportation workshop report a couple of years ago, and as far as I know there is no such study in existence, and I think I make the point later that I agree that there should be.

I should also say that our ability to engage in this sort of work, if you want to call it R. & D., I guess it certainly is a portion of R. & D., is limited, because a regulated industry just can't very well have a big R. & D. budget.

Chairman MILLER. Well, I am not going to accept that. Railroads have been regulated for years. The trucks and every other mode of public transportation are under regulation. It reminds me a great deal of the history of the Southern Pacific Railroad, in my home State. The Southern Pacific Railroad got pretty well control of the politics of California in the early days. Then, driving the railroad over the Sierra Mountains was one of the biggest engineering feats, and an outstanding engineering feat in this world.

But the result is that the people who drove it over the mountain then took charge of the railroad. I used to work for the Southern Pacific Co., over 50 years ago, as a young engineer. We didn't mind holding up "No. 1," which was the overland limited train, if something had to be done in the mechanical side of fixing a track or something.

And this went on for years until the public was forgotten. It was the big thing; we got a railroad and it had to be operated. They began to lose out and then they changed some of their management and set forth in the other direction.

Now, operating airplanes is to a degree comparable. The changes that have taken place in the last 20 years have been great. The changes that will take place will be equally so. But, I wonder if the people who operate the planes don't let the mechanical side of it sometimes dictate a little bit what is going to happen.

We want the plane here and we want it there. And the dickens with the passenger; let him walk. Now, most of the European airlines at least take you out in a bus to the plane. I once thought that Dulles was for the birds when I first saw it. But, the more I have traveled, and I think I have landed on nearly all of the major airlines in the world—in Europe and parts of Asia—the more I see Dulles, the more I think that it is the optimum type of operation.

You waste a little time getting back and forth. But, by the time you get in, your suitcase is only about 5 or 10 minutes behind you, which is more than you can say in most airports. Taken on the whole, there are no great distances to walk.

To me it is the optimum. I wonder why someone hasn't studied this program and come up with it as a better airport, and then have local people copy that type of airport.

O'Hare isn't so old that it couldn't have been improved on. Do you like to go to O'Hare and walk around those long distances?

General VON KANN. I prefer Dulles, sir.

Chairman MILLER. How about Kennedy, if you want to go from one to another?

General VON KANN. I prefer O'Hare to Kennedy.

Chairman MILLER. And San Francisco; I live on the east side of the bay. We hope to have a good airport at Oakland someday. But I have to walk great distances in San Francisco.

General VON KANN. Yes; we do. We do. Well, sir; I would like to say this, if I may, that going back to my point that there is a limit to the amount of R. & D. that an industry in our position can do, I still feel this is true. We do what we can. For example, in the last year or so we have put nearly $2 million into a collision avoidance system.

You will find that airlines will dig into their pockets as deeply as they can on safety, but then with the finances being what they are they probably are not going to be able to go into too many other areas, especially with the varying jurisdictions involved in airport development.

We should do more. We are doing more. But I think the largest problem here is the fact that you have got one-third of the system in the hands of private enterprise, one-third in the hands of the Federal Government, and the other third in the hands of lord knows how many entities.

Chairman MILLER. I understand, I appreciate it, and I am not critical. I think I understand your problem. But I do think that if maybe 10 years ago—and I knew some of your predecessors pretty well—if they had given thought to this, you would have started prodding the Federal Government at that time, and we might have had some of the solutions now.

General VON KANN. I couldn't agree more. I think a lot of people could have looked forward more energetically, and I can't disagree with your point.

Chairman MILLER. Well, of course, you people involved in a medium of transportation, have the most to be gained if we can do something in this field. Thank you.

Mr. HECHLER. Thank you, Mr. Chairman.

Are you on page 7?

General VON KANN. Yes, sir.

With respect to connecting facilities, particularly intermodal connections, I have equally serious concern. There will be improvements; but in the overall, the problems preventing improved access will be at least as serious as the obstacles to increased airport capacity. Therefore it is difficult to foresee any widespread solutions.

Intramodal connections may see some improvement, although it appears that new technology must be brought to bear to facilitate interline transfers involving long distances. New techniques for transfer of people and baggage will be needed. While it would appear that

some steps may be taken to meet these needs, a better approach would be to eliminate or greatly reduce the need for these transfers.

The problems attending our effect on the environment and quality of life will probably be with us during the coming decade and beyond. The latter seventies should see the beginning of some technological solutions to these problems.

By that time jet aircraft engines will be virtually smokeless. Hopefully they will be somewhat quieter. Current NASA and military helicopter blade noise research should bear fruit by that time. Nevertheless we cannot anticipate a change in the prevailing American attitudes toward technological progress; these will not only hamper the acquisition of new airports, but also the programs to increase airport capacity.

To summarize the prospects for the U.S. air transport system in the seventies, it appears that, given the present level of R. & D. effort, the following problems will be most urgent toward 1980:

One, inadequate capacity at major hub airports.

Two, increasing difficulty in acquiring new sites for major airports.

Three, inadequate access systems to airports by way of other transport modes.

Four, increasing difficulty in intramodal passenger connections.

Five, increasing difficulty in adjusting air transport systems to environmental factors.

On the other hand, the air traffic control system will be approaching adequate capacity, jet engines will be somewhat quieter and nearly smokeless, and helicopter and propeller blade noise will have been significantly reduced.

If this forecast is correct, there will be an urgent requirement to reduce traffic at major hub airports because of inadequate runway capacity and inadequate airport access capacity. This in turn means that there must be greater use of direct flights between city pairs, and preferably between downtown areas where major cities are concerned. Only by VTOL, STOL, and V/STOL systems can these needs be satisfied.

It is evident that during the early seventies STOL technology will provide the initial hardware for developing these auxiliary short-haul city center systems. This will be due to the lower costs and immediate availability of STOL systems. However, there are technical and consequent economic limitations to STOL which probably cannot be overcome until a practical V/STOL system emerges.

For example, a STOL aircraft has its minimum control speed, and it approaches this minimum at the most critical point in the operation, the final approach and landing. Possibly this problem may be overcome or reduced by new techniques such as blown flaps. However, the economic trade-offs remain to be seen, and for STOL aircraft some forward speed will always be necessary. Minimum control speed will not be a problem for VTOL's or V/STOL's which, having powered lift and control systems, can stop or even back up and which require no runway.

The potential economies of STOL are realized in proportion to length of runway required. The less runway required, the higher the cost because the greater the need for auxiliary lift systems. At

some point the power and control required approaches that of V/STOL.

While some of these limitations may be modified, there is a very definite limitation in the STOL requirement for airspace. A slow-moving STOL may need far less airspace than a jet; however, it needs far more than a helicopter or V/STOL, which can be given much tighter spacing in the air (and on the ground, too) with equal safety.

Simultaneous instrument approaches—the key to efficient use of terminal airspace—will be harder (and more costly) to bring off with STOL's because of the missed approach requirement. For V/STOL there is really no missed approach requirement.

As for real estate, it is fairly certain that V/STOL systems will require less than STOL systems. In view of these economic and technical limitations, it would seem that unless V/STOL research and development is allowed to lapse, the next decade should see V/STOL pass STOL in cost effectiveness in the high-density areas. The more aggressive the R. & D., the sooner this will come to pass.

We should therefore not delay in recognizing the urgent requirement for V/STOL short-haul systems in the 1980's to provide downtown air transport service between city pairs at stage lengths of up to 500 miles. As the state of the art improves these stage lengths will increase.

It is recognized that short-haul systems cannot be limited to downtown service, and that some interconnections with longer range service must be carried out at major airports. Whatever the problems of these interconnections, they will be easier to solve with V/STOL systems.

Now, on R. & D. requirements for the 1970's, from this size-up we can now visualize where our major R. & D. efforts should be made if technology is really to be directed toward solution of our major problems.

As I have indicated, the R. & D. needed for the ATC system has been or is being spelled out fairly clearly. What will be needed here will be adequate funds and good systems engineering.

It has already been reported to this committee that more airport R. & D. is needed. The point was made in the report of the transportation workshop of 1967 and by the National Academy of Engineering in 1968 in its assessment of Federal Government involvement in civil aviation R. & D.

It was also made in last year's hearings by Mr. F. W. Kolk of American Airlines. All I can do is to reiterate the point and emphasize that the program has yet to be spelled out. I must add that the one overriding need is how to get local jurisdictions to work together in airport planning. Whether any R. & D. can help solve this problem is open to question.

While connecting facilities are vital to the ease and efficiency whereby passengers are moved between airplanes and other transport modes, there seems to have been a good number of separate projects, but little in the way of systems research aimed at new concepts. Thus a passenger may be traveling at 500 miles an hour while airborne, while a few minutes later at his destination he finds himself in a frustrating

struggle to move himself and his baggage at a ground speed of even 1 mile an hour.

As I have noted, there are many individual R. & D. projects aimed in this direction. For example, the ATA–IATA study on automatic ticketing and reservation will greatly improve the lot of the passenger in the ticketing process. Also, automated baggage handling systems should also be of value.

There are numerous local studies on moving people at airports. However, the matter of interconnection as part of a total system has not, in my opinion, been effectively addressed. If the Government is to look at transportation in the overall and to seek greater balance between transportation systems, this matter of interconnecting and intraconnecting facilities needs additional attention. A few suggested areas for R. & D. would include more comprehensive origin and destination data gathering, studies on removing nonessential functions (and people) from airport property, human factors research in the transfer process, and the cost effectiveness of air versus ground distribution systems.

As I have indicated, the conclusion is inescapable that STOL and VTOL technologies, which might well merge into a single V/STOL technology in the 1980's, offer the best prospect of relieving the pressure on large airports and airport access systems by providing short-haul downtown-to-downtown air service.

Because of the large military investment in V/STOL (something over $250 million during the past 15 years) and the continuing work of NASA, there is an excellent technological base from which to work, and it is fairly certain that economically viable V/STOL systems can be developed for this purpose at far less cost than high-speed ground systems.

However, the recent environment in the Department of Defense has not been favorable for continued effort in V/STOL R. & D. This comes at a particularly unfortunate time, since helicopters currently in civilian service are second-generation helicopters while those coming into the military service represent third-generation technology.

If this technology could be transferred to civil applications the results would probably be economically viable hardware. Certainly the next generation, which will probably take the form of compound helicopters, should have DOC's well within the economically acceptable ranges, that is, 3-cent seat-mile cost or less.

While STOL technology seems to be receiving an adequate level of effort in NASA's programs, it does not appear that there is a sufficiently aggressive R. & D. attack in the VTOL area to make the small additional effort which is needed to bring this technology to a level where it can be integrated into a national air transport system.

The probable reason for this deficiency is best described in the transportation workshop report on pages 251–254. This section is appropriately titled "The Impasse." After reading it, one can only ask the question "Who's in charge here?" and the answer seems to be "nobody."

In peculiar contrast to its excellent program for applying supersonic technology to the air transport system, DOT-FAA has no counterpart project at the short-haul end of the spectrum. It has made some worthwhile efforts to utilize available STOL technology; but

there is no comprehensive program for followup with useful V/STOL hardware, for developing the auxiliary elements which will be needed for the air traffic control system to handle V/STOL's, and for sponsoring a national program to provide the necessary ground environment when it is needed.

Two weeks ago I discussed this problem while giving a lecture in Tokyo to the Japanese V/STOL Research Association. And I will also offer a copy of that paper for the record.

(The document follows:)

REMARKS BY MAJ. GEN. CLIFTON F. VON KANN, USA (RET.), VICE PRESIDENT, OPERATIONS AND ENGINEERING, AIR TRANSPORT ASSOCIATION OF AMERICA, IN TOKYO, JAPAN, NOVEMBER 24, 1969

V/STOL PROSPECTS, 1970–1980

It is always a joy to return to your great and beautiful country, of which I am so fond and for which I have such deep respect. It is difficult to say whether the artistic and intellectual achievements of Japan or its economic and technical progress are the more impressive. Both have justly earned the admiration of the world.

I approach the subject of V/STOL with considerable humility. There is really little that I can say which your illustrious and able Mr. Ryohei Ito does not already know. His study of V/STOL throughout the world is the most comprehensive effort of its kind that I have ever seen.

In this light my main contribution will perhaps be to indicate what developments I anticipate and what important questions about V/STOL remain unanswered.

Let me begin by defining my terms. When I say VTOL I am thinking of any aircraft that can land or take off without a ground run. My definition also includes the ability to hover, for I doubt that VTOL's will be fully exploitable without this capability.

A STOL aircraft by design has some degree of powered lift and control and requires a relatively short ground run for takeoff or landing. I prefer not to attempt to determine the exact amount of ground run at this time since STOL has not yet been defined technically—at least in any generally accepted manner.

V/STOL's or VTOL's which can be operated with a ground run to take advantage of available short runways and thereby to achieve increased payload and/or performance. Most VTOL's are V/STOL's. I believe that during the 1980's advances in aeronautical technology will bring VTOL and STOL very close together, technically and economically.

Having defined my terms, however loosely, I propose to cover four main topics: first the status of VTOL and STOL; secondly, the status of civil air transport in the United States; thirdly, the prospects for the 1970's in the United States; and, finally, a few comments on your situation in Japan as I see it.

Status of VTOL and STOL in the United States

VTOL technology has advanced more rapidly during the past 15 years than perhaps any subsonic aircraft technology during a like period in aviation history. The U.S. Department of Defense alone has invested about $250 million in V/STOL research and development. It is unfortunate that this effort was not better coordinated and that it was subject to many internal disagreements. Nevertheless, it greatly advanced the state of the art. In addition, the National Aeronautics and Space Administration (NASA), the Federal Aviation Administration (FAA), U.S. industry, and the scientific community together have invested perhaps another $50 million. Free world nations such as the United Kingdom, France, West Germany and Italy have made important and lasting contributions to the V/STOL reservoir. And the efforts of the USSR have also been impressive and productive.

The product of this extensive technical effort has been a massive technology bank to support continued engineering refinement of today's helicopters and a rational basis for design of the third generation V/STOLs now emerging. A physical manifestation of this technology bank is seen in numerous research, experimental, and preproduction prototype V/STOLs now flying. Each of these

in turn is backed up by additional component and subsystems hardware in various stages of wind tunnel testing, engineering validation, and other test work.

We therefore have a technological supermarket offering the manufacturer and potential customer a variety of design alternatives depending upon his particular needs.

After shopping today's technological supermarkets, what emerges is a picture of technological alternatives to support construction and operation, in the mid-seventies, of a family of advanced V/STOL machines in the 40, 60 and 90 passenger sizes with speed, range and payload comparable to several short haul transports now in airline operation. Seat mile costs could be between $.04 and $.05 compared to figures of more than $.07 for current scheduled helicopter service. The technical and operational risks are probably less than those of the SST, and comparable to those of the jet transports introduced into airline service ten years ago.

In the 1980's it will be technically feasible to construct V/STOLs in the 120 to 200 passenger sizes with speeds comparable to those of today's subsonic jets. With speeds and payloads of this magnitude, seat mile costs should approach $.03 and this would permit highly profitable operations. There is increasingly convincing evidence that in this time frame the technological/operational difference between STOL and V/STOL will largely disappear.

To assess the role of V/STOL in 1970–1980 short haul intercity transportation (500 miles) the FAA completed a contract study with McDonnell in 1966. In this study ("Technical and Economic Evaluation of Aircraft for Intercity Short Haul Transportation"), and in the supporting effort ("An Analysis of Intercity Passenger Traffic Movement Within the California corridor through 1980"), the scheduled airline use of V/STOL and STOL aircraft in 1975–1980 is evaluated. Using 1970 technology three representative V/STOL designs and one STOL design configured to 60, 90 and 120 passenger transports are used. Special V/STOL and STOL air terminals are sited for downtown passenger convenience and land use compatability to minimize the operational noise level. Cost benefit evaluation includes operation in the California Corridor compared to simulated jet transport operation for the same period. The conclusion of this study is that "the time savings and convenience of VTOL/STOL airline service would enable these aircraft to capture a substantial share of the short-haul air travel market and would induce additional air travel."

It is interesting that the FAA-McDonnell study shows that both STOL and V/STOL are economically viable. An earlier study by the Massachusetts Institute of Technology, ("A Systems Analyses of Short-Haul Air Transportation") with the operations model set in the Northeast Corridor, indicates that V/STOLs have an economic advantage over STOLs because of the lower investment for vertiport facilities. More on this later.

The general conclusion of these two studies—both cast in geographical areas with existing and profitable short haul markets—is that regular V/STOL short haul (under 200 miles) service will divert revenue traffic from auto, bus and rail, and that scheduled V/STOL service will be profitable to the operators and owners.

The aircraft manufacturing industry has also taken a position on future V/STOL growth. In a 1966 report, "The Economics of VTOL", prepared by the Vertical Lift Aircraft Council of the Aircraft Industries Association, an analysis of present and future V/STOL aircraft capabilities is made, especially of intercity short haul in the mid-seventies. This study examines combinations of routes up to 300 mile stage lengths including city center to city center, city center to airport, and airport to airport operations. STOL aircraft are not considered after initial determination that total costs of the larger, more elaborate facilities required are not competitive with the costs of V/STOL facilities. However, where runways are available, as in the case of operations from long haul jet airports, it is recognized that greater payloads can be carried by the V/STOL in the STOL mode of operation. The greater operational flexibility and lower vertiport terminal costs are determined to be significant economic advantages for the V/STOL system.

The basic conclusions of this 1966 report still appear to be sound although there is now evident a growing role for true STOL transports in the early 1970's as part of the necessary transition from CTOL to V/STOL in the next 10 years.

Now, let me show you visually a few examples of current STOL and VTOL technology. (Film).

Here are a few pictures of the de Havilland *Buffalo*, a turbinized version of the original U.S. Army *Caribou*. Using Buffalo technology de Havilland now plans to go into production with a STOL transport of about 50 passengers—the DHC-7.

The de Havilland Twin Otter is already in service throughout the world. It was the first of an increasingly large number of small 18-20 passenger transports. As of last December there were 59 Twin Otters in scheduled service by U.S. commuter airlines—more than any comparable type of aircraft.

Next the CL-84 Canadair tilt wing, a V/STOL engineering prototype that has gone beyond the test bed stage. The tilt wing approach is the most practical conceptual approaches to non-military V/STOL. In the United States there is great interest in tilt wing technology on the part of Boeing-Vertol and Ling-Temco-Vought, as you will soon see.

Another technical approach is illustrated by the British Hawker-Siddley P-1127—also known as the *Harrier*. This approach uses vectored thrust by rotating the main engine exhaust ducts to produce downward thrust in the VTOL mode. The P-1127 has been in existence for nearly a decade and has flown across the Atlantic—with refueling. This is the only V/STOL aircraft now in small scale production (for the Royal Air Force).

Finally, there is the Ling-Temco-Vought XC-142. This vehicle is unique in that it is an operational protoype (about 3 ton payload) built by the Department of Defense, with participation by the Army, Navy and Air Force, so that the tilt wing concept could be given an operational evaluation. By and large it has performed well, but its economies in its present configuration are not suitable for commerical use. However, the manufacturer has attempted to illustrate the possibility of commerical use, and this part of the film shows how such a vehicle might look if in commercial service. (End of film).

The compound helicopter technology is already well proven through much engineering flight test in the U.S. for the military. Various manufacturers have proposed designs of commercial compound helicopters. Here (slide) is a picture of Sikorsky's concept of a commercial passenger compound helicopter—the S-65-200. This aircraft could carry 86 passengers a distance of 230 miles or 60 passengers a distance of 500 miles. No technological problem here, and Sikorsky would go into production tomorrow if enough orders were to be placed. (Slide off).

Another technical approach to VTOL is the tilting rotor (Slide)—a concept supported by the Bell Helicopter Corporation which built the first prototype (the XV-3) over 15 years ago. This technology is entirely feasible; however, the size of the rotor precludes practical STOL operations, so this ship is VTOL only. (Slide off).

A more advanced concept, and one needing more research and development, is the so-called disc-rotor or rotor wing helicopter. In the Hughes concept (Slide), the disc is triangular; and when the rotor is stopped the helicopter becomes a delta-wing aircraft capable of subsonic speeds. This is a very exciting concept; it could be realised within a decade if sufficient R&D funds were to be made available. (Slide off).

Just to show that cargo has not been neglected, I have a few feet of film showing the Sikorsky Flying Crane which is now operating successfully in the oil drilling operations in northern Alaska. (Film).

Finally, I have a slide of a helicopter which may very well lead the way to VTOL city-center to city-center service. Here is the Gates twin jet business helicopter soon to go into production. (Slide). While it is difficult to establish a scheduled operation between cities I believe that the advantages and economies of business operations between city centers will result in early and successful use of business helicopters in this role. (Slide Off).

Expanded use of helicopters and compounds should be facilitated by reduction in engine blade noise. The U.S. Department of Defense is supporting some encouraging research work by engine and helicopter manufacturers.

Status of Civil Air Transport in the United States

As you know jet engine technology brought a transportation revolution to our country about ten years ago. Today most of our public intercity (Slide) travel is performed by air. In 1958 the airlines accounted for 39.3% of the passenger miles performed in public intercity transportation. In 1968 the airlines' share was 72.5%. In intercity travel of 200 miles or less, the private automobile is still the most popular mode of transportation; but even here the airlines have made inroads. (Slide off).

This revolution affected the whole free world. Twenty years ago, (slide) in 1949, the airlines of the free world flew about 15 billion passenger miles; in 1968 the number had increased to nearly 200 billion; by 1980 this figure could approach a trillion passenger miles. (Slide off—next slide on).

The air freight statistics are equally exciting: 350 million ton miles in 1949; 4.8 billion ton miles in 1968; perhaps 30 billion ton miles in 1980; more if the new giant cargo jets, like the L-500, are utilized to their full revolutionary potential (Slide off).

This growth in air transport has been spearheaded by the aircraft and engines. Fortunately, during the 1960's the old airport and air traffic control systems were able to support the increased traffic without excessive strain. Now, however, the strain has become excessive; and today we have a crisis in airport and air traffic control capacity—especially in our higher density areas.

Let me describe our problems in some detail for an understanding of these problems is needed if the future is to be assessed intelligently.

I believe we have four major areas of concern in the U.S. air transport system. These are:

1. Operational facilities (airports and airways).
2. Connecting facilities (inter-modal and intra-modal).
3. Our effect on the environment and the quality of life.
4. Finance (a direct result of the other three problems).

With respect to operational facilities the problem is complicated by differing organizations. The Federal government is responsible for the airways. On the other hand airports are built and operated by a variety of local jurisdictions—sometimes directly and sometimes through authorities deriving their charter from one or more of the political jurisdictions involved. Obviously, this results in different motivations, different pressures, different ground rules. It does not make for expeditious action that can recognize and satisfy air transport requirements. Whether the relatively new Department of Transportation in the Federal government can help to find solutions remains to be seen.

The problems of connecting facilities are of another type. Let us first consider inter-modal connections, i.e., transfers between aircraft and other transportation modes—taxi, bus, limousine, private auto, train, or subway. With few exceptions, airport access systems do not support the peak needs for inter-modal connections, and this can make the rush hour at our larger hub airports a nightmare for the passengers. Since the other travel modes must be provided by non-aviation jurisdictions and since they must also satisfy non-aviation needs, the problems of keeping them in balance with the requirements of air transport are staggering.

But even connections between aircraft pose formidable problems—at least for the passengers. Despite the fact that the airlines spend a great deal of time and effort working out convenient connecting schedules, these schedules can never be ideal for everyone. Where the system runs into serious delays—as it often does today—interconnecting passengers may fail to make their connections (notwithstanding earnest efforts by the airlines to protect their customers).

Even if there were no problems with connecting schedules, the growth in air traffic, in the size of airports, and in distances between different air carrier gates (this may amount to several miles at the new Dallas/Fort Worth Airport), it is becoming more time consuming and difficult for passengers to make interline transfers. This problem will require new airport technologies—or at least the extension of existing ones.

Even helicopter connections between downtown and the airport have serious problems. These are necessarily high cost air operations. More serious, the passenger often has to use another transport mode between the helicopter (or STOL) and the airliner.

Turning to the third problem area, our effect on the environment and the quality of life, this is the most recent major development, perhaps the most urgent, and surely the most complex.

The complexity is due to changing social attitudes in the United States. For most of the last 100 years we were a nation dedicated to industrial and economic growth through technological progress. To a great extent people had to get out of the way of technology, and this was not unreasonable because we had plenty of room. If people were unhappy about the noise of trains, trucks, or boat whistles they could go somewhere else.

But now our urban areas and many of our suburbs are crowded—similar to the way in which yours are crowded. Many of our people are having to learn

to live under more crowded conditions, to wait in line, to make accommodations to one another. They are having to learn amenities which a few generations ago seemed less important.

At the same time our political leaders and the judicial system are insisting that the environmental needs of individuals be given greater consideration and that the quality of their life be protected.

For example, just a few weeks ago in Arlington, Virginia an architect built a rather modernistic home with a box-like shape in a neighborhood containing middle class one story ramblers. The new home offended the neighbors who took him to court. Although he had broken no laws or zoning codes, the court ordered the architect to move his house or tear it down, notwithstanding an investment of over $30,000. Such a court decision would have been unthinkable even 20 years ago.

Almost equally surprising was the recent reaction to the jet training airport which the Miami, Florida airport authorities are attempting to build near the Everglades. This project was undertaken innocently enough in an effort to reduce aircraft noise and air traffic congestion in the Miami area. However, a highly emotional reaction resulted, with many claims and counterclaims as to the effect on the wildlife of the Everglades. At this time the true facts are unclear, and so is the outcome. The point is that to an ever increasing extent technological considerations must be balanced with environmental ones; and the air transport system finds itself in the middle of this issue.

As you know the airlines are under great pressure to reduce jet aircraft noise—even though there is no easy or immediate solution. Noise restrictions at various airports have already reduced the available capacity of these airports. Recently there has been agitation for the airlines to eliminate the black smoke exhaust from jet engines even though this smoke is negligible as a pollutant and has some safety benefits in that it increases conspicuity of our transport aircraft.

This concern for the environment is also affecting airport construction. It is becoming more and more difficult to obtain approval of a new airport site—or to improve and expand existing airports. The benefits which an airport brings to a community tend to be forgotten in the strong concern for environmental integrity.

All of these problem areas involve tremendous costs. Some are already borne by the airlines; others will probably follow. These uncertainties have raised questions as to the future growth and profitability of our industry, which in turn affects the ability of the industry to raise capital for new equipment which we need for productivity and for growth.

Prospects for the 1970's in the United States

Our efforts to solve the above problems will dominate the greater part of the next decade. I believe that the extent of our success or failure will be determined largely by the extent to which V/STOL technology is utilized in the civil air transport system of 1980. I will now attempt to forecast the extent to which we will succeed or fail.

We need to know only two facts about operational facilities: (1) whether there will be an adequate airway system in the next decade; and (2) whether there will be an adequate airport system.

I believe we will achieve adequate airway capacity by the late 1970's. Federal user charge legislation which will provide the necessary funds is all but certain to be enacted. The technology for the necessary automation of the air traffic control system is available or can be made available in the desired time frame. The necessary authority exists in the Federal Aviation Administration. The only question lies in the ability of that Administration to manage and engineer the program. In the light of the background and expressed intent of the present Administrator, one must assume that the necessary systems engineering can be accomplished within the government. If not, some other organizational arrangements may be necessary. But I still believe that the job will be done.

With airports there is less cause for optimism, mainly because it will be nearly impossible to build by 1980 any new airports whose site has not already been selected and approved. In short it is no longer possible for more than a very few new airports to appear in the U.S. during the next ten years. So while the anticipated user charge legislation may facilitate airport financing, it would appear that these funds will be used mainly to improve existing airports—actually to stretch existing capacity as far as it will go and thus to delay the evil day when the airport becomes the ultimate bottleneck in the system. With the jurisdictional problems involved in programming these improvements, and the pressures of

noise abatement efforts toward reduced capacity, it is impossible to foresee adequate capacity at the major airline airports in the coming decade.

With respect to connecting facilities, particularly inter-modal connections, I have equally serious doubts. There will be improvements; but in the overall, the problems preventing improved access will be at least as serious as those facing increased airport capacity. Therefore it is difficult to foresee any widespread solutions.

Intra-modal connections may see some improvement, although it appears that new technology must be brought to bear to facilitate interline transfers involving long distances. The ATA/IATA research in automated ticketing and reservation will be useful here; new techniques for transfer of passengers and baggage will also be required. While it would appear that solutions are possible, one must ask whether or not the best way to solve the problem would be to eliminate or greatly reduce the need for these transfers.

The problems attending our effect on the environment and quality of life will probably be with us during the coming decade and beyond. Possibly the latter seventies will see the beginning of some technological solutions to these problems. By that time jet aircraft engines will be virtually smokeless. Possibly they will be somewhat quieter. Current military helicopter blade noise research should bear fruit by that time. Nevertheless we cannot anticipate a change in the prevailing American attitudes toward technological change; these will not only hamper the acquisition of new airports, but also the programs to increase capacity at existing airports.

To summarize the prospects for the U.S. air transport system in the seventies, it appears that the following problems will be most urgent toward 1980:

1. Inadequate capacity at major hub airports.
2. Continued difficulty in acquiring new sites for major airports.
3. Inadequate access to airports and aircraft from other transport modes.
4. Difficulty of intra-modal passenger connections.

On the other hand the air traffic control system will be approaching adequate capacity, jet engines will be quieter and nearly smokeless, and helicopter blade noise will have been significantly reduced.

If these conditions prevail it becomes clear that there will be an urgent requirement to reduce traffic at major hub airports because of inadequate runway capacity and inadequate airport access capacity.

This in turn means that there must be greater use of direct flights between city pairs, and preferably between downtown areas where major cities are concerned. Only by VTOL, STOL, and V/STOL can these coming needs be satisfied.

It is evident that during the early seventies STOL technology will provide the initial hardware for developing these auxiliary short haul city center systems. This will be due to lower costs and immediate availability. However, it must be recognized that there are technical and consequent economic limitations to STOL which probably cannot be overcome until a practical V/STOL system emerges.

A STOL aircraft has its minimum control speed, and it approaches this minimum at the most critical point in the operation—the final approach and landing. Possibly this problem may be overcome or reduced by new techniques such as blown flaps; however, the economic trade-offs remain to be seen. For STOL aircraft some forward speed will always be necessary. Minimum control speed is not a problem for VTOLs or V/STOLs which, having powered lift and control systems, can stop or even back up, and which require no runway. I believe that more attention should be paid to the technical papers of Walter P. Maiersperger of our Research Analysis Corporation in this regard.

This raises another point of great interest. The potential economies of STOL are realized in inverse ratio to length of runway required. The less runway required, the higher the cost. At what point does the cost curve approach VTOL costs?

Since a STOL needs at least some ground run, it has crosswind and turbulence problems at least equal to other fixed wing aircraft; and there will be times when STOLs, too, go off the side of the runway. This raises a question about the practicality of downtown rooftop operations.

Speaking of rooftop operations, these present no operational problems for multi-engine V/STOLs; however, it remains to be seen whether wind and turbulence conditions in the vicinity of rooftops will pose operating problems for STOL aircraft. The pinnacle approach is no problem for the helicopter. What

it may be to a STOL at the time of the flare and initial touchdown to a rooftop runway needs investigation.

This in turn raises another possible limitation with STOL operations—that of the steep gradient approach. If STOLs are to approach at 6°–7½°, the flare must be executed at precisely the right altitude, particularly under low visibility conditions. Leaving out the possibility of pinnacle wind effects, this operation will probably require fairly sophisticated cockpit equipment. (The pilots will probably insist on such equipment). Here again a multi-engine V/STOL can handle much steeper gradients (up to 12°) with safety.

While some of these limitations may be subject to modification, there is a very definite limitation in the STOL requirement for airspace. A slow moving STOL may need far less airspace than a jet; however, it needs far more than a V/STOL, which can be given much tighter spacing in the air (and on the ground, too) with equal safety. Simultaneous instrument approaches—the key to efficient use of terminal airspace—will be harder (and more costly) to bring off with STOLs because of the missed approach requirement—which for V/STOL is not really a requirement.

As for real estate it is fairly certain that V/STOL systems will require less than STOL systems. In view of these economic and technical limitations it would seem that unless V/STOL research and development is allowed to lapse, the next decade should see V/STOL pass STOL in cost/effectiveness. The more aggressive the R&D, the sooner this will come to pass.

We should therefore plan on V/STOL short haul systems in the 1980's to provide downtown air transport service between city pairs at stage lengths of up to 500 miles. As the state of the art improves these stage lengths will increase.

It is recognized that short haul systems cannot be limited to downtown service, and that some interconnections with longer range service must be carried out at major airports. Whatever the problems of these interconnections they will be easier to solve with V/STOL systems.

While there are numerous hardware approaches to commercial V/STOL, a low noise level is such an important requirement as to dominate the list. This means low disc loading. Thus the compound helicopter continues to be my choice for the first intercity downtown to downtown V/STOL service.

Whether we are considering the STOLs of the 1970s or the V/STOLs of the 1980s, it is evident that these vehicles must be reasonably large in order to keep the DOCs low and for easier interfacing with the higher capacity jets. It is difficult to specify the optimum size, but I would assume that as time goes on and traffic continues to grow, the capacity and productivity of the vehicles should also continue to grow, a time honored phenomenon in air transport.

Coming Operations in Japan

I am informed that at this time your interests in V/STOL are directed mainly at service between the new international airport at Narita, downtown Tokyo, and Chofu. I am further informed that the initial service will probably be provided by STOL aircraft because of the more favorable economics.

Apparently your plans do not envision rooftop operations, and I must agree with this. We need to know a great deal more than we now do before it will be prudent to take STOL aircraft to rooftop levels—or even to runways on piers, for that matter.

In considering the projected passenger flows at the new airport, I have used a table which was presented at the IATA Seventeenth Technical Conference at Lucerne in October, 1967. (Slide). It forecasts the hourly passenger flow for the New Tokyo International Airport in 1976. I presume that a more current forecast would not be too different. One notices immediately that during only one hour of the day—from 1800 to 1900—is there a balance between arriving and departing passenger. During the other hours there will be a tendency for the STOL service to be running very light loads in one direction or the other.

The other problem that I see from this forecast is that of peaking. The hourly average for enplaning passengers is 434, and for deplaning passengers it is 446.

Yet during the 1700–1800 hour there will be almost 1300 arriving passengers, and over 1700 from 2100 to 2200. This raises questions as to what the maximum level of STOL service should be, and what can be done to utilize the equipment profitably during the less busy periods. (Slide off).

Now it would be presumptious for me to try to suggest solutions to these problems. The point is that they have presented themselves before, they have been solved before, and I'm sure that they will be solved here. They must be solved if the passengers are to be spared an intolerable long ground [illegible] between Tokyo

and Narita—a trip which will last as long it takes to traverse the first 1000 miles across the Pacific.

There is a related problem—and one which will demand creative innovation on your part—this is the question of schedule frequency and STOL flights available to arriving international passengers. As we know it is difficult to predict westbound arrival times with accuracy. It is also difficult to forecast how long it will take to clear customs and immigration. At Kennedy this process may vary from 40 minutes to an hour and a half. You will have to do better than this at your new international airport if there is to be an even flow of arriving passengers proceeding from incoming jets to the STOL aircraft bound for Tokyo. I would hope that during the next few years we improve facilitation procedures—using preclearance, if necessary—to a point where there is minimum delay in processing arriving passengers.

In any event it would appear that you will have difficult decisions ahead with respect to sizing and frequency. As I have said the larger size STOLs and V/STOLs make sense economically. However, they provide less flexibility than do smaller aircraft providing greater frequency. Where to draw the line calls for great wisdom.

Now in making these decisions I hope you will not be discouraged by the recent discontinuation of STOL service between airports in the Washington-Baltimore area. There are many differences between that situation and the Tokyo-Narita-Chofu picture. For one thing the distances involved in the Washington-Baltimore area are relatively short, so the airplane has less advantage over ground transportation. For another, the roads in the Washington-Baltimore area are very good; even in the rush hour, it rarely takes more than 45–50 minutes for ground travel from downtown Washington to Dulles or Friendship airport.

It therefore seems to me that the two situations are quite different, and that air connections here should provide a far more useful public service than anywhere else in the world—a suitable result in view of the thorough and careful studies which Mr. Ito has made.

In forecasting a successful STOL service here, however, I must add that I foresee this service as an interim arrangement which will be replaced by V/STOL service in the early 1980's as V/STOL economics overtake those of STOL. For the reasons I have outlined above, the greater flexibility of V/STOL in the air and on the ground, its ability to penetrate built up urban areas, its greater safety—it is only a question of time before this transition becomes necessary. However, it is appropriate and wise to initiate the service with STOL; and this is a pattern that will occur with great frequency in the United States in the decade ahead.

In many respects your needs for efficient, short haul air transport are the same as ours. We will be watching with much interest how your STOL, V/STOL needs evolve during the next few years. And certainly we hope we may continue our cooperative efforts to plan and create V/STOL systems in the next decade.

I thank you for the opportunity to offer you these observations.

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General VON KANN. Since there doesn't seem to be a national program for bringing V/STOL into the system, but since I also feel that it has to enter the system at some point in time, I forecast that this will occur during the 1980's. A very distinguished Japanese airline official said to me, "How can you afford to wait until the 1980's?" I could not answer this question, but I can repeat it to this committee with the comment that we need V/STOL now. We could have it now had we moved aggressively in the past, but at the rate we are going it will be another 10 to 15 years, which will be far too late.

Mr. HECHLER. At that point, what precisely is needed now in order to do what you are suggesting?

General VON KANN. I have recommended in the past, sir, that within DOT or FAA, the matter of the problem of bringing V/STOL into the air transport system be looked upon as a single overall problem, and the various objectives and subprograms in three fields be laid out, what needs to be done.

First of all, there would be the hardware development. What needs to be done there to bring about economically viable hardware. Second, in the air traffic control system, what needs to be done so that the system can accommodate these kinds of aircraft.

And finally what can be done at the national level to insure that there will be a ground environment which will take V/STOL's. Right now again in many local jurisdictions, there are restrictive laws and ordinances being enacted which 10 years from now will probably make it more difficult than ever to bring this kind of air transport into the city center airports.

So I think studies are needed or actually data gathering should be initiated. A great deal of O. & D., origin and destination information is needed. We should be starting to gather the data bank so that we

can find out where the people are coming from, what kind of transfers will be needed.

In other words, an excellent effort was made in the Government to bring supersonic technology into the system, and I applaud it with all my heart and I greatly regret the problems that they have in keeping the program going. But I cannot understand why at the other end of the spectrum, the short-haul end, which is equally important, some, if not exactly parallel effort, some comparable effort is not advisable.

I see many projects in FAA bearing on this subject, but I don't see it all being pulled together in a systemlike way, and that again raises the question, who is in charge? And in one of my former papers, I even went so far as to recommend that there ought to be an associate administrator of FAA for V/STOL systems.

This is the kind of approach I would like to see, and if it is there, I have not identified it, at least.

Mr. HECHLER. As you know, this committee and members of this committee have frequently made the observation that we should have a national aeronautics and aviation policy enunciated at the highest level. Do you feel that if we did have such a policy that it would be of any assistance?

General VON KANN. I think it would, sir, and I have been encouraged by some of the testimony earlier in the course of these hearings. As a matter of fact, as I will point out in my closing paragraphs, I think a lot is underway now in the joint DOT–NASA study, and in what appears to be the future course of the National Aeronautics and Space Council, to bring about this sort of a grasp of the problem, and as a policy statement, and I am very much encouraged by these developments.

I just hope they keep moving.

Mr. HECHLER. Thank you. You may proceed.

General VON KANN. Yes, sir.

Now, as to the problems attending our impact on the environment and the quality of life, I expect that these may not seem serious in contrast with those of other industries. On the other hand, they are very serious for us because they can affect our economic viability.

In our effect on the environment, the principal areas of difficulty appear to be jet aircraft engine noise and the imminence of the sonic boom which is expected to accompany commercial supersonic flight. While we are having some difficutly at this time because of the smoke emitted by certain jet engines, this is largely a problem of esthetics rather than chemical pollution of the air; and because of the voluntary industry programs mentioned earlier, all jet engines will be smokeless well before the end of the coming decade.

The reduction of jet engine noise is a much more serious problem and calls for an even greater R. & D. effort than we have seen to date. The statement submitted last year by Mr. R. W. Rummel of Trans World Airlines provides an excellent summary as to where expanded R. & D. programs aimed at noise suppression are required. Nothing that I can say can improve upon Mr. Rummel's statement.

The subject of sonic boom generated by supersonic aircraft has been the subject of so much uninformed discussion that one is loath to raise the matter at all. On the other hand, it would seem that a greater effort

now to understand sonic booms and find out how to reduce their signature would pay tremendous dividends in about 10 years when supersonic commercial air transport becomes commonplace. The current level of effort seems to be rather minimal, and it is difficult to believe it could not be stepped up by orders of magnitude.

Mr. HECHLER. Of course all the official statements are that the sonic boom problem by SST is not going to exist, because it is not going to fly over the continental United States.

General VON KANN. Well, we should also have the objective, though, of making the SST a good neighbor over land areas as well as over water areas or desert areas. I agree that it can't—the sonic boom being what it is—but I believe we have a problem there that we should be trying harder to solve.

My concluding comments, sir.

While I have attempted to describe the general areas requiring additional civil aviation R. & D. effort from the standpoint of the realities of the next decade, I must point out that nothing I have said is really new. The airline group which appeared before this committee last year, and of which I had the honor to be a member, made virtually all the same points.

The Transportation Workshop, which was organized in 1967 and produced an excellent report in 1967, covered these same areas with great competence. Finally, the National Academy of Engineering in its 1968 report covered the same list in a somewhat more abbreviated fashion. What concerns me is the fact that during these 2 years, while all these problems were widely recognized, civil aviation R. & D. programs appear to have changed but little.

It therefore seems to me that the emphasis needs to be on action rather than on further testimony. Yet I do not want to imply that nothing is being done. As I have pointed out, the necessary R. & D. in air traffic control has been spelled out project by project.

Further lack of action here will simply be an admission that air congestion is not regarded as an important problem. There has also been movement in the dialogue between DOT and NASA which has resulted in a joint understanding between these two organizations on how to approach civil aviation R. & D. This understanding is being followed up by the joint DOT–NASA civil aviation R. & D. policy study.

This study should produce a more careful definition of the specific projects needed to flesh out the general problem areas I have discussed. It is very important that this study be supported on a high priority basis, and this committee should interest itself in the results, both as to timeliness and content.

While my remarks have been directed mainly toward R. & D. in relation to the operational and environmental aspects of the air transportation system, I do not intend to imply that R. & D. directed toward further increasing the safety and productivity of conventional airplanes is not important. Many items in this area were mentioned in last year's testimony by airline representatives and in the 1968 report of the National Academy of Engineering. Undoubtedly they will also be included in the joint DOT–NASA study.

I am encouraged by what seems to be an increased effort on aeronautical R. & D. in NASA; however, I must state quite frankly that

more work needs to be done to insure that NASA programs are responsive to user requirements. Possibly the DOT–NASA study will produce positive results in this respect.

And I might say, sir, that since I drafted these remarks, I have had the opportunity to see Mr. Anders' testimony of last week, or was it earlier this week? And here again, I see an encouraging sign in the apparent direction of the National Aeronautics and Space Council, and again I hope that these two efforts do a great deal to spur on this policy statement which you suggested, and the need for which I heartily suscribe to.

As this committee knows, the world leadership in aviation which we formerly enjoyed without question can no longer be taken for granted. If we lose our technical superiority it will be a disaster both militarily as well as economically. The level of effort in our civil aviation R. & D. in the seventies will, I think, be the decisive factor in whether we fail or prevail.

Thank you, sir.

Mr. HECHLER. Thank you, General von Kann. I appreciate very much the thoroughness of your statement, and also I appreciate your tolerance in terms of our interrupting you during it.

General VON KANN. No problem, sir.

Mr. HECHLER. It was so challenging, some of the things you said, that it stimulated a lot of inquiry. Mr. Goldwater, do you have some questions you would like to ask? If not, I would like to pose this question.

General VON KANN. Yes, sir.

Mr. HECHLER. How much do you pay attention to cargo in your association?

General VON KANN. Well, quite a bit, sir. I may have to submit something for the record here, because my own department is not the main element in looking into this. But our association was very active in the work to standardize the containers, which of course has a marked effect on cargo economics.

Mr. HECHLER. Well, I am not so much interested in the details of how you transport cargo, as how you equate the means of transporting cargo with the very problems that you raised here, about airports, for example. It seems to me that you ought to think of this whole picture in terms of the economy and your moving cargo as well as people.

You can't simply say, well, we will push that problem aside and have a separate airport out here for cargo and another one here for people.

General VON KANN. No, I don't think we are going to be able to push it aside, because the planes just don't come out the right way for that. All your big new jets coming into the system will have a lot of room in their bellies for cargo, and this will have to be done.

Mr. HECHLER. Considering cargo, and cranking that into the total picture, would you make any further observations on the problems that you have raised here?

General VON KANN. Well, they are certainly part of the problem, sir, and what I would like to do is perhaps to go back and see if we have some material prepared that could be submitted.

Mr. HECHLER. That would be helpful.

General VON KANN. Bringing the cargo part into this, which is largely passenger oriented, I will admit. We actually all think of the passengers first, because they are human and the cargo isn't.

Mr. HECHLER. That is a very important factor in the development of our economy, and we know it is going to be with us. I just want to make sure that we anticipate some of the problems, physical and otherwise.

General VON KANN. A lot of work has been done and I will report on that for the record, sir.

Mr. HECHLER. Thank you.

Mr. GOLDWATER. I do have a question. There has been a lot of talk about air traffic control, the problems of congestion and inadequate systems. What is the attitude of the Air Transport Association toward the possibility of alleviating some of these problems by placing the responsibility in the cockpit instead of on the ground, or rather more of it into the cockpit?

I am not saying that the pilots don't do anything. But there has been talk of instead of putting all the responsibility for traffic on the ground, putting it in the cockpit.

General VON KANN. Yes. Well, there is some thought along this line, and this can be done. As a matter of fact, there are some proposals in our study here, in that regard. For example, we have supported the use of area navigation systems, which is really a high-class word for knowing more accurately in the cockpit where you are in relation to the ground.

And we support the idea that by the use of these systems, you can take a great deal of workload off of the controllers, because you can clear a pilot to follow a given route almost from one airport to another. As a matter of fact, I hope in time we see him cleared from runway to runway.

And most of the work would be done in the cockpit. Also, your automatic communications, digital communications will do a great deal to unload both the pilot and the controller. So you can do some of this. On the other hand, the central brain of the system, this big central computer that is going to have to know where everybody is, will probably have to be on the ground.

But a lot can be done, and I think a lot is coming into the system right now that will be helpful in that respect.

Mr. GOLDWATER. I think your association certainly has a great responsibility. As Chairman Miller pointed out, probably you people above all can be more valuable to developing an overall system because you actually use it.

One thing keeps cropping up in my mind, and I guess I sound like a stuck record. But it is probably because I am part of this problem, and that is the area of general aviation and the problem that it creates for commercial aviation. It always seems that the emphasis is on commercial aviation, somewhat at the expense of the weekend pilot.

But the weekend pilot does cause a lot of problems in the transportation industry. I am just wondering, in your suggestion to develop this system, if you have made recommendations for the handling of general aviation in relationship to handling of commercial aviation?

General von KANN. Yes. That is developed in our report, and of course it is treated in very great detail in the DOT-FAA advisory committee report. I might say in answering this question that I work for the airlines, but I also fly a small plane myself, so I think I have got a fair amount of sympathy.

And my feeling is that we simply have to make arrangements so that everybody has a reasonable chance. The country needs a thriving general aviation establishment. We lead the world in general aviation as well as transport aviation, and I don't want to see either one go by the board.

We export a lot of aircraft, too, of the smaller types. So I think we have to aim for a system where we give general aviation ample room to grow. Now, I must say this. I think that in reaching this better world, both sides are going to have to give up certain things.

We have had to back off in certain areas. For awhile, 3 or 4 years ago, the idea of corridors was repugnant to airlines, and you can see why. You don't like to have to go down the river, all in this so-called elephant line. Now we are recognizing that in some areas this is going to have to be done.

I think general aviation will have to make some, will have to accommodate itself in certain areas. I think that largely it will bear on qualification of equipment and pilots in the higher density city areas. But on the other hand, there are only a few high-density areas, and all the airlines in the country only use 500 out of about 10,000 airports.

But I just think we have got to do more at working this thing out and both have got to give a little and somehow we have got to make it so that both, all elements of the industry thrive and grow.

Mr. GOLDWATER. I am sure your suggestion would be very valuable in developing this thing.

General von KANN. Well, we have made some. The Alexander group has made others. Their intermittent control concept is really the key to giving a general aviation opportunity to operate in the so-called crowded airspace. But we concentrate a lot on it.

Every airline does not agree with every other one on how to go about it. But I think that we are making progress toward a realization that everybody has got to have a chance to live in this air.

Mr. GOLDWATER. In somewhat of a minor area, are the airlines having difficulty in finding people that want to become pilots? Is this a problem?

General von KANN. No, not at this time. There seem to be plenty of people. Of course you have got a lot of military pilots who leave the service, and want to go into private industry. You probably know from seeing the salary scales that it is not too bad-looking to a fellow who has been getting along on military pay.

In the area of the mechanics, that is taking more of an effort to keep ourselves well-manned there, and we are working with some of the educational bodies toward better aviation training, so that the various curricula have the necessary technical courses so that 5, 10 years from now you won't be running out of avionics types.

Avionics will be one that we have got to watch. But on the pilot area, no problem there as of now.

Mr. GOLDWATER. Do pilots have certain proficiences and proficiency tests they take twice a year?

General VON KANN. Yes, they take checks of about that interval.

Mr. GOLDWATER. Airlines have to find runways to make touch and go landings. As a matter of fact, just one such runway is in California, at Edwards Air Force Base, where something like several thousand touch and go's were made just in 1 month.

General VON KANN. Yes.

Mr. GOLDWATER. Is this becoming a problem, the finding of adequate runways?

General VON KANN. It is not yet a serious problem, but it is something we have got to watch. Now, up to now you can find enough, you know, former military airfields, things like that, or low-density airfields. I know in Los Angeles they used to run over to Palmdale a lot. I don't think they are doing it as much now.

As you say, they use Edwards. The problem really is to get that sort of a field near enough to their base that they don't spend a lot of time going back and forth. Naturally they would all like to have it 10 miles away, as they have to move further out it becomes somewhat of a problem.

But now in places like Florida, it is a very different one, and we have all heard about the recent discussion on this training airport. I think in that part of the country it is tough. In other parts of the country they have seemed to be able to find military or former military bases that are reasonably adequate.

Mr. GOLDWATER. Someone brought up the point in the discussion here that in relationship to noise, that perhaps the airlines should be making a greater degree of angle of approach to the field on their final glide slope—what is it, 3 degrees now?

General VON KANN. Yes, 2½ or 3 degrees.

Mr. GOLDWATER. There is talk about a steeper descent.

General VON KANN. Yes, that has been discussed. And I think probably in time there will be more of that, because you do get some alleviation, you get several PNdB's by steepening the slope. Now, the trouble there is that with the current cockpit equipment, I don't think anybody is about to do it, because when you, you know, we have had a few bad ones in the last 3 or 4 years because of too great rate of descent and overly steep approaches.

So I think with the current equipment, your safety is going to require that you stay somewhere around the 3-degree glide slope, particularly in the final stages.

Work is being done to push it up to, say, 6 degrees, out further, maybe as you would approach the outer marker, 6 degrees, and then gentle your slope and come in. Trouble is that really doesn't buy you too much, because then it is in the last 5 miles that you are getting most of the complaints.

So you are going to have to have better control equipment in the cockpit, in my opinion, before pilots are even willing to talk about a steep approach toward the point, toward the point of flare. No reason why it can't come in time. But it is not here yet.

Now, with STOL's, we are talking about 6 to 7½ degrees, and I think it remains to be seen even with the STOL's whether we have really got all the gear in the cockpit that you or I would want as a

pilot to make sure we flared at the right time, did the right thing soon enough, because you just have got too much at stake if you miss.

With V/STOL's, of course, better yet, and I think that is another reason why we should be interested in V/STOL, because the idea of getting up in the air almost over the airport is very, very alluring from the standpoint of noise alleviation.

Mr. GOLDWATER. Yes. That is all I have.

Mr. HECHLER. Thank you very much, General von Kann. I appreciate very much your coming before the committee.

General VON KANN. Well, I will submit the additional information.

Mr. HECHLER. Very good. Before we conclude this morning I would like to simply indicate that last year this committee received some excellent testimony from Charles H. Ruby, president of the Airline Pilots Association, and a number of pilots who accompanied him. We asked Mr. Ruby this year to testify, and I regret very much that he was unable to work that into his schedule.

We then asked Mr. Ruby to submit pertinent material that he felt would be of benefit to us in these hearings. I have received a listing of 17 recommendations, of areas wherein the Airline Pilots Association feel that additional research work is required.

I urge that attention be focused on these recommendations and that action be taken where required. Some of these recommendations are specifically in the realm of the NASA research and development and I hope that attention can be directed by NASA to these recommendations.

It is difficult for me to say where product improvement normally carried out by the manufacturers and research effort by NASA is required. However, it is obvious that as large aircraft become operational carrying upward of 400 passengers we cannot fail to recognize the seriousness of flight safety items.

As a result, I urge all those concerned to study this list and see firsthand the primary items that concern those who actually pilot the planes. Without objection, this material will be included in the record of these hearings at this point.

And if there are no further questions from members of the committee, the committee stands adjourned until 9 a.m. tomorrow.

(Whereupon the subcommittee was adjourned, to reconvene the following morning, Thursday, December 11, 1969, at 9 a.m.)

(The document follows:)

AIR LINE PILOTS ASSOCIATION,
Washington, D.C., December 3, 1969.

Hon. KEN HECHLER,
Chairman, Subcommittee on Advanced Research and Technology, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: This is to express the views of the Air Line Pilots Association today with respect to the activities in the field of aeronautical research and development and the need for additional research and development that will be required to meet the problems of airline pilots operating aircraft in scheduled air transportation. To be of as much assistance as possible to the subcommittee, we are highlighting problem areas which have repeatedly caused catastrophic accidents due to lack of research and development and also lack of application of completed research and development for accident prevention. Some of the problem areas have had research and development to the point where airplane design and operational regulatory action should be taken. We have given consideration to try to foresee what new types of accidents of a repetitive nature could occur. We believe the problem areas, which are set forth on the following pages, require research and development not only for solving today's aeronautical

problems, but also as we visualize for aeronautical problems of the next ten years and beyond.

As you are aware, on October 3, 1968, we presented ALPA's views to the subcommittee with respect to aeronautical research and development needs for increasing the safety and efficiency of air transportation. We believe the information we presented at that time is still of prime concern; however, we would call your attention to the problem areas of air traffic control improvements and collision avoidance system and proximity warning indicators. We are particularly concerned that research and development in the ATC and pilot warning devices for collision avoidance have not progressed satisfactorily.

We respectfully request this material be made a part of the record of the public hearings of the subcommittee on aeronautical research, which began on December 1, 1969.

Sincerely yours,

CHARLES H. RUBY, *President*.

AIRCRAFT

1. Airframe Integrity

The record of aircraft accidents shows that we continue to have potential structural failures in airline aircraft, due in some cases to metal fatigue, or the operation of the aircraft into unknown turbulence of such magnitude that the design load factors are exceeded and catastrophic prime structure failure of the airframe occurs. We believe additional research should be conducted, in the public interest, to determine whether or not the airplane's fabrication alloys are becoming so exotic in composition that while they are strong enough to meet the current certification requirements, the question is are they strong long enough for the life of the airframe. Also, a study should be made to reascertain whether the current gust load strength formulas for certification of aircraft are adequate to minimize the possibility of an overload failure occurring with catastrophic results.

The subcommittee is aware that in the past, after such accidents occur, the airliners are either "grounded" or flown with severe restrictions until they have their structural defects eliminated by reinforcement or improved design. These air transports have been certified to rules which reflect the current state of the art. Studies to determine whether or not current regulations for airframe strength requirements and metal fatigue prevention requirements are adequate should be undertaken for today's fleet and apply all findings to all future airplanes.

Commendably, one air carrier is currently engaged in an extensive wing structural improvement to add strength and stamina to the large transport they are operating. We consider that the item of airframe strength and life strength falls within the scope of the hearing and warrants very serious and thorough review by the subcommittee.

2. Avoidance of Augmentation Means for Stability and Control of Aircraft

Through research and development, the requirements for flight control of transport aircraft by aerodynamic systems should be determined. The present trend of stability and control augmentation contaminates the flight control system and when a malfunction occurs, loss of control of the aircraft can result. Research and development should be conducted to determine the aerodynamic design needed for stability and control of a transport aircraft throughout the operating flight envelope without augmentation, or a design such that, when it fails, the pilot can safely hand-fly the airplane.

3. Catastrophic Effects of Turbine Engine Disintegration

The turbine engine has developed into a remarkable reliable power plant for airline use. Its time between overhauls has reached undreamed of flight hours, 10,000 or more on some engines. However, turbine engines are composed of high speed rotating parts which upon disintegration have force of a missile fired from a sizable cannon. The disintegration of only one or more of the major high speed rotating components of the turbine engine has the capability of producing a catastrophic structural failure to the extent that the airplane is no longer controllable and a fatal crash results. We are at present flying approximately 2,400 airline aircraft with more to come that have turbine powerplants installed. Coordinated research and development is required to assure that when high speed rotating turbine engine parts disintegrate, the parts will either be contained within the engine compartment, or deflected into the free air without

striking the airplane. In addition, a warning system of instrumentation should be provided to warn the flight crew in sufficient time so that the failing powerplant can be shut down before the destructive disintegration occurs. Such a warning system would tell the pilots to mechanically stop turbine rotation prior to disintegration, which may be a way to prevent the destructive effects of a failing turbine wheel or blades.

4. In-Flight Fire Prevention and Post Crash Fire Prevention

Commendable research has been done to minimize in-flight fire and post-crash fire; however, the research time and money spent has been somewhat of an exercise in futility. This is because this dynamic industry is advancing so rapidly in producing new advanced airline airplanes that time has not been taken to incorporate all known means to minimize in-flight fire possibilities, and since they can occur, positive fire prevention research has been completed in regard to minimizing fuel spillage due to broken lines, torn tanks, water inerting of the powerplants, and undoubtedly some other detailed items. However, the record of catastrophic in-flight fire exposure continues, and catastrophic post-crash fires continue to occur. This is an area where coordinated research and development of hardware, promptly installed in airline airplanes, can minimize the continued loss of life and property due to the effects of aircraft fires either in-flight or following a survivable accident.

5. Clear Air Turbulence Instrumention

Research and development should be expedited to produce clear air turbulence instrumentation which will enable a transport airplane to be flown without overstressing the airframe and without injuring passengers. Some research and development, including hardware, is presently being service tested. We urge the subcommittee to take whatever action it can to expedite research and development in this area, since this type instrumentation is needed not only for the present airliners, but will be vitally needed for supersonic flights.

6. Sabotage Prevention

The threat of some deranged person sabotaging an airline airplane is still with us. While extensive research and development has been conducted and is continuing, it would be well for the subcommittee to delve deeply into this area of continued accident exposure to determine if a sufficient coordinated research and development effort is under way. In our opinion, with the airline aircraft continuously increasing in size, the exposure to the loss of a large airline airplane becomes greater.

7. Control of Irrational Passengers

A continuing problem of airline pilots is the control of irrational passengers. These may be passengers intent on sabotaging the airplane by shooting the flight crew, hijacking the aircraft, or becoming uncontrollable due to fright or other reasons. To date, we do not have a method or means in effect for rapidly incapacitating a person intent on pursuing any of the actions previously mentioned. A survey of the research and development status in regard to controlling irrational passengers should be undertaken so that a coordinated effort can be made to determine which the the most promising efforts of producing the desired result and expediting the necessary studies and research.

8. Airplane Noise Reduction

Airplane noise has been a problem to the citizens living in the vicinity of the airports practically ever since the airline transport-type airplanes were used in scheduled air carrier operations. As the state of the art of aircraft and engine design advanced, the airplane noise problems grew proportionately. Citizens on the ground near the airport are really seriously affected by airplane noise and their complaints should not be disregarded. Research to minimize airplane engine noise is in progress. Installation of airplane engine noise suppression systems is in the test stages and some promise for relief is indicated. In some cases, engine noise can be alleviated by penalizing engine thrust; however, the economics of the airplane may be adversely affected to the point where the amount of decrease in engine noise that is required to satisfy the citizens will result in an airplane which is uneconomical to operate. Research should be expedited to determine where the compromises between the airplane engine noise suppression and the resultant loss of power versus controlling land use in the vicinity of the airport must balance. Since the transport airplane

is increasing in size as well as the powerplants, the technology required to determine tolerable noise levels for the U.S. citizen is a vitally needed research area for improvement for today's aircraft and obviously a must for tomorrow's aircraft with their more powerful engines.

NAVIGATION OF AIRCRAFT

1. Air Traffic Control Improvements

Considerable research and development for improved air traffic control has been under way for a number of years. These efforts have produced some favorable results although the number of aircraft in the system has consistently outdistanced the capability of the ATC System to effectively handle them. While the planned automated enroute and terminal control systems will possibly provide some relief, we believe it is largely a case of "too little—too late."

It is obvious that the integration of the large Boeing 747 type aircraft as well as the Supersonic Transport into the existing and proposed airline fleet will add considerably to the ATC problem. The fantastic growth of the general aviation fleet, to an estimated 214,000, in 1980, will also provide many additional problems to the Air Traffic Control System. As is well known today, the air transportation industry is in the midst of a "congestion crisis" and there is little hope that current plans will alleviate the crisis.

Research and development, at a greatly increased rate must be undertaken at once, if complete chaos is to be averted. Such research should be directed along lines other than those which have been followed in the past, since it would appear that there is little to be gained in this direction to meet the future needs of air traffic. It may be that, in order to supplement current development, research should be directed towards procedural and regulatory improvements, rather than to continue to rely entirely on hardware. We believe the current plans for the implementation of Terminal Control Areas, as proposed by the Federal Aviation Administration, should not have been thrust upon the industry without a great deal of research to determine the most effective configuration. The applicable rules and procedures were also issued without adequate research to determine their effect upon the flying public. It is because of events such as these, that ALPA firmly believes that there must be a tremendous increase in the research and development effort, it we are to ever have a safe and efficient Air Traffic Control System.

Improvements in air traffic flow can be realized rapidly by an expedited airport development program since the airport is today, and can become increasingly so, the bottleneck for the whole system.

In recent months, we have seen the advent of "area navigation" into the operational environment. The FAA, although moving slowly in permitting its implementation on a wide basis, has developed methods whereby prospective users may install and utilize this new equipment. It is essential however, that research and development be continued at an ever increasing pace if the Federal Airway System is to cope with the tremendous increase in air traffic that has been forecasted.

One of the fundamental ingredients in today's air traffic control problem is the vast amount of oral communication by means of radio which is required by the ATC system. Although considerable research has taken place to overcome this problem through the use of data links or digital air-ground communications, there are few indications that the development aspect has progressed satisfactorily. The present system is slow, cumbersome, and wasteful of the frequency spectrum and is subject to many human errors, which require much time consuming repetition of messages essential to flight. These problems can be corrected only through expedited research and development programs.

2. Collision Avoidance Systems and Proximity Warning Indicators

ALPA considers that an improved ATC system must provide the basic separation between aircraft which operate within the National Airspace System. It is vitally essential, however, that a "back-up" Collision Avoidance System be provided to enable pilots to take evasive action when the ATC System fails or may not be available. A redundant airborne Collision Avoidance System must become available as soon as possible and mandatory installation required in every aircraft.

While the airlines, through the Air Transport Association are developing a Collision Avoidance System its cost and complexity are such that it is improbable that many general aviation aircraft will be able to afford its installation. Since

less than 1% of the mid-air collisions in five years involved two airline aircraft, it is obvious that airline aircraft and general aviation aircraft must be provided with a means to avoid collision with each other. Furthermore, since more than 90% of the mid-air collisions during the same period were between two general aviation aircraft, it is even more obvious that some form of Pilot Warning Indicator (PWI) must be made available for these aircraft.

As we stated to your subcommittee on October 3, 1968 "—consequently, collision avoidance instrumentation suitable for all airplanes should be provided at the earliest possible date. An examination should be made of the current effort of research activity and also whether or not adequate funding has been provided to expedite these requirements."

A low cost short range Pilot Warning Indicator (PWI) is the only hope for producing a means for pilots to avoid mid-air collisions. They can be installed in all types of aircraft, (small civilian, large civilian, airline and military aircraft). The PWI, due to its low cost, can be installed in airliners even though they may have the greatly needed sophisticated ATA Collision Avoidance System equipment now in test stages. This would provide a back-up in the event that the CAS installed in the airliner becomes inoperative or has limitations in the terminal area.

The PWI matter has been active since at least 1956. On June 1, 1956, the RTCA published a report entitled "Operational Requirements—Proximity Warning System." The requirements were so severe for a PWI that apparently no progress was made and the matter became dormant. The NASA Research Advisory Committee on Operating Problems, in October 1965, decided that the mid-air collision problem was not being adequately researched. A strong resolution was passed along with appointment of an Ad Hoc Committee to determine what research was being done. The Ad Hoc Committee delved into the matter and found no R&D going on for a PWI. This is substantiated by the fact that when NASA Electronic Research Center and NASA Langley Research Center delved into the problem, they had to start with basic research to determine PWI concepts and design requirements.

More than three years have passed since the NASA Research Advisory Committee on Aircraft Operating Problems passed its strongly worded resolution to highlight the importance of the problem. It is inconceivable that page 2 of the recent NASA Report No. TN-5174 titled "Compilation of Data from Related Technologies in the Development of an Optical Pilot Warning Indicator System" states the research effort was conducted "mostly on a less-than-full-time basis." This is a shocking statement in that the mid-air collision problem is so serious that the research should have been conducted and continue to be conducted on an overtime basis. Directing attention to this report is not intended to adversely reflect on the NASA scientists and the commendable research they have conducted, but rather to focus attention that their efforts should be augmented and adequate funds be provided without delay.

In view of the almost complete lack of expediting progress in this vital area, ALPA *once more stresses the tremendous need for a* full-sized and adequately funded research and development program with the objective of having Pilot Warning Indicator equipment available to the general aviation operator at a price he can afford. Past and current efforts along this line have been predicated on criteria which we feel are much too demanding for a low cost PWI. ALPA considers that the first step in this direction should be to develop a low cost, short-range PWI. Once this type of system is in common use, then steps can be taken to "glamorize" it by increasing its range, improving its instrumentation, etc., for those that can afford more sophisticated equipment. However, we do feel very strongly that every effort must be made to develop the low cost, short-range PWI without delay. The justification for this type of equipment lies in the fact that, over a period of five years, some 89% of the mid-air collisions occurred 25 miles or less from an airport, about 77% took place at an altitude of 3000 feet or less, and approximately 98% had a closure speed of less than 250 knots. In this regard, in the public interest, a realistic target date, preferably not more than one year, should be established for the commencement of PWI implementation into the general aviation and airline fleets.

It is only through action such as ALPA proposes that the mid-air collision hazard can be eliminated, or at least minimized.

3. Clear Air Turbulence Forecasting

There should be an increasing research and development effort made for providing a clear air turbulence detection instrumentation and forecasting service for efficient and safe flight planning. Even though clear air turbulence detection

instrumentation may be installed in the airliner, it is still desirable to avoid the turbulence in the first place by flying in areas where it will be non-existent or minimized. To minimize the effects of clear air turbulence when it is detected by instrumentation will require the pilot to either slow down the aircraft, which is undesirable especially at high altitude, or make extensive enroute deviations to avoid continued exposure. Either course of action is undesirable from the standpoint of safety and economics due to the additional requirement for either slow flight through the turbulence or detouring around it, as both are time consuming. Clear air turbulence detection instrumentation is vitally needed. Techniques for forecasting clear air turbulence are also vitally needed and will enable flight planning for maximum safety and economics.

4. Airborne Radar and Weather Improvements

Transport aircraft are being designed to fly at higher and higher altitudes; particularly future aircraft being planned. High flying aircraft require radar which is capable of providing the pilot with information regarding the weather. Specifically, the need is to develop radar capable of functioning at high altitude where low moisture density exists.

An explanation of the foregoing appears pertinent. The present weather radar is really a storm detection device. Its principle of operation is based on the energy transmitted from the aircraft being reflected back to the receiver in the aircraft by moisture particles associated with the storm area. The greater the moisture density, the better the picture on the radar scope.

In the lower levels, this is a very satisfactory system of storm detection, enabling the pilot to thread his way through a detour as required. As flight altitudes increase, the total moisture density decreases with a resultant loss of the radar picture that enables the pilot to determine the severity of turbulence associated with the storm area because at the higher altitudes the total moisture density in each cubic foot of airspace is materially reduced. Either further development or improvement of the present radar systems for weather avoidance purposes is needed or new development is indicated.

5. Standardization of All Aircraft Instrumentation and Navigational Facilities

Development of satisfactory testing equipment and calibration facilities are absolute essentials for flight instrumentation as well as flight navigational systems in order to provide accuracy of readouts on each aircraft type. Therefore when the conglomerate is operating in the same airspace all altitude references are accurate and identical, as well as airspeed readings and Mach meters being identical. Flight navigational systems must have the same relative relationship, one to the other, with respect to the geographical position of all aircraft operating in the airspace.

The foregoing are simply examples of what must be done if we are to obtain efficient and economical use of airspace with a high level of safety. Once system errors are compensated for with sophisticated checking equipment, a long stride will have been made in providing accuracy for instrument readings which will report the various parameters they are designed to record.

Present aircraft and their associated navigational facilities and instrumentation require improvement in terms of accuracy and relationships one to another.

AIRPORTS

1. Airport Development

We foresee a continuing need for the next ten years and beyond for research and development of our airport system. At the larger metropolitan areas this must also provide for the access of people and goods into and out of the airport.

There is very little need in the way of airport safety and efficiency research. What is needed is recognition of the present and future needs and the money to provide for these needs. Extensive airport safety and efficiency documentation is available to the committee not only from this Association, but also from other industry segments. The problem *has now become widely known* and the foreseen "airport crisis" is now with us as it will be for some time—unless known steps for improvement are promptly taken.

2. Fog Dispersal for Safer Takeoffs and Landings

The record will show that, historically, the Air Line Pilots Association has been actively participating in pursuing ways and means to accomplish all weather flying safely. At certain times, the ALPA groups of a particular air carrier have

advocated lowering minimums for a certain type of aircraft, based on their collective experience relating to the handling of the airplane and the integrity of its instrumentation. At other times the pilot groups of an airline have fought against lowering of minimums for certain types of airplanes, again based on their experience and not having the confidence needed for flying lower minimums. ALPA and its members also recognize the merits of automation such as autopilots and automatic landing instrumentation. However, automatic equipment of all types are subject to tolerances and failures. In this regard, for zero-zero takeoffs and landings, the Air Line Pilots Association urges expedited research and development to disperse fog from a sufficient distance ahead of the threshold and down the runway length to the point where the pilot, in monitoring an automatic approach, can see enough to be sure that the automatic equipment will place him at the proper touchdown point for landing and the continued high speed rollout or so that he can either take over and make a missed approach, or take the proper corrective action to complete the landing by manual control. Such research and development is vitally needed and is in the best public interest for safe air carrier operation.

FLIGHT RECORDERS

1. In-Flight Recorder Instrumentation for Airplane Airworthiness

The great need for the airliner's flight crew being continually cognizant of the airplane system reliability while in flight becomes increasingly important as the air transports increase in complexity and size. Research and development for producing reliable "in-flight" recorder instrumentation will enable the flight crew to:

a. Take the proper safety precautions to minimize the possibility of an accident.

b. Conduct in-flight reporting to ground maintenance regarding a developing fault in the airplane's systems, etc., and thereby maintenance personnel can take appropriate action to reduce the expensive "down time."

c. Keep an accurate log of repeated faults of the airplane's systems and, thereby, enable justifying research and development for improved design reliability of the airplane's components.

2. Flight and Voice Recorders for Accident Cause Determination

The deficiencies of today's flight recorders for accident analysis are well known. Of concern is that the original flight recorder accuracy instrumentation do not duplicate the accuracy of the instruments that are installed in the flight compartment. Additionally, there should be spot checking to assure that flight recorder accuracy is maintained. Since flight recorder use requires working with small increments of time (seconds), it can be readily appreciated that there must be accuracy in the recorder's original installation as well as the need for maintaining this accuracy.

The Association has long stressed that flight recorders must always be recovered undamaged following the accident. The Association has maintained that flight and voice recorders for accident investigation must be capable of:

a. Ejection upon impact so that it is clear of the burning wreckage.

b. Readily located by means of a homing signal.

c. The ejected recorders should remain floating on the water surface.

In addition to the previously listed requirements, the number of flight recorder parameters for obtaining information to analyze the cause of an accident should be increased from the present meager five, plus a voice recorder to a sufficient number of parameters so that "the guessing" of what is happening to the airplane is reduced to the most practical minimum. Continued recorder accuracy is a prime necessity.

The state of the art of flight recorders is advancing rapidly. By expediting the implementation of improved units for fleet installation of these sophisticated recorders, we will obtain the data to know the TRUE cause of an accident. Immediate preventive measures can then be taken, and also the data thus obtained can be studied to determine areas requiring research for prevention of similar accidents and improving economics.

CONCLUSION

It would be difficult to place a meaningful priority of the R & D need we have mentioned to which the pilots and air traveling public are exposed in scheduled air carrier operations.

We are aware that the air carriers have placed record breaking orders for new aircraft. These orders are for aircraft that will closely resemble the design and operation of the current fleet of airliners. The present fleet and new orders for essentially the same type of airliner will be in service for approximately 20 years. Unless research and development is expedited, the same types of fatal accidents which have occurred throughout the years will continue for the next 20 years.

We should carefully examine whether or not we are implementing "break throughs" of aviation research and development areas which prevent accidents from occurring and also examine ways and means to achieve *future* prevention of the accident type where no preventive "break through" has occurred.

There are, no doubt, many other areas which would enhance safe and economical air carrier operations such as foolproof airplane assembly methods, improved inspection to minimize the possibility of losing an airplane due to a missing cotter pin, etc. However, we have limited our comments here to the need for required technologies to meet the demands of the next decade and beyond and to a direct examination of the adequacy of the national research and development efforts in the field of aeronautics.

We have provided herewith a number of items which we believe are, and will continue to be, of great concern to the airline pilots, air carriers, and the air traveling public. We are hopeful that our statement will be productive to assist in enhancing aeronautical research and development for manufacturing and operating airline transports with increased efficiency and safety.

AERONAUTICAL RESEARCH

THURSDAY, DECEMBER 11, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON ADVANCED RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 9 a.m., in room 2325, Rayburn House Office Building, Hon. Ken Hechler (chairman of the subcommittee) presiding.

Mr. HECHLER. The committee will be in order.

We are pleased to have this morning Mr. James C. Elms, the Director of Electronics Research Center.

Welcome back to the committee, Mr. Elms. We appreciate the testimony you gave last year, and we also appreciated our visit to your center. We hope you can bring us up to date on what the center is doing, and what you plan to do in the field of aeronautical research and development.

STATEMENT OF JAMES C. ELMS, DIRECTOR, ELECTRONICS RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. ELMS. Well, Mr. Chairman, I do welcome the opportunity to be here the second time, and to describe the work that is being carried on at the Electronics Research Center in avionics, a word which covers electronics-related areonautical research and development.

My testimony and statement at this subcommittee hearing on September 25, 1968, discussed specific programs in aeronautics as well as six areas of research being performed by ERC that are related to both aeronautics and space.

In the past year, ERC has continued its research efforts in these six areas, in many cases with an even greater emphasis on their applications to aeronautics. These areas are—

Electronic components and devices—especially the application of microelectronics and large scale integrated circuits to advanced avionics systems;

Guidance—the application of advanced technology to instrumentation for sensing, and controlling aircraft motion and attitude;

Optics and microwaves—atmospheric propagation, communications, electromagnetic sensing;

Data processing—the interaction between computers, displays and man;

Physiological instrumentation; and

Electrical power systems.

In addition to these six areas of research, ERC has continued the specific programs which are specifically related to aeronautical research and development, and has made several new starts in fiscal year 1969. At present, ERC has 14 such specific programs, which represent about 30 percent of ERC's R. & D. and manpower expenditures.

These programs will be described as they relate to the NASA electronics research role in the areas of air traffic control, collision avoidance, navigational and communications satellites for aviation, and support technologies. All of these areas are included in the ERC program, but reference is also made to some of the complementary programs in these categories at Ames, Langley, Flight, and Lewis Research Centers.

Now, NASA's general approach in the field of aeronautical electronics research is to emphasize development of onboard systems and components. A more effective onboard capability will take better advantage of the ground systems established and operated by the FAA.

One example will help clarify this point. Several years ago, an attempt was made to reduce North Atlantic traffic lane widths from 120 miles to 90 miles. This did not happen because pilots argued, and argued successfully, that their ability to navigate was not sufficiently accurate. More precise and reliable onboard navigation systems will permit narrower lane widths in the future, which will result in a capability for handling a higher traffic density with equivalent safety.

I will now discuss our present program as it is related to air traffic control. Programs have been established in NASA, partly as a result of discussions with the FAA, which will aid in providing solutions to problems resulting from the increasing traffic density. They emphasize onboard capability. They further are addressed to the needs of three important classes of users of the system—conventional jet transports, V/STOL, and general aviation.

ERC initiated a conventional jet transport program jointly with the FAA in 1969 that is directed initially toward the reduction of touchdown position and velocity dispersion during the final approach of an automatic ILS landing. The FAA is providing a Convair 880, as well as facilities at NAEFEC in Atlantic City, N.J. ERC is supplying the onboard guidance equipment. I think that it is important to point out that the design of this first phase system does not require major items of new equipment. Instead, the system will use presently available components. The research involves the logic of interconnecting these components so that value and precision of information is increased. The benefits to the air traffic control situation from this program are expected to be a reduction in missed approaches through greater landing accuracy with existing ILS performance levels.

An extension of the automatic landing program is planned to begin next summer. This will provide high precision automatic control of aircraft in the terminal area, in addition to the landing phase. This will increase the acceptance rate of aircraft at airports. In this case, precision control is an essential capability for closer sequencing of aircraft in the terminal area and approach phases. It will also permit

automatically controlled curved precision approaches to aid in reducing approach times and avoiding noise-sensitive areas. Planning of this program is based on current discussions underway with the FAA.

Mr. HECHLER. Excuse me, Mr. Elms. You mentioned that this refers only to conventional jet transport?

Mr. ELMS. That is correct for this particular program. I am going to describe other programs later that relate to V/STOL and also to general aviation.

Mr. HECHLER. Thank you.

Mr. ELMS. But this particular one applies to conventional jet transport.

Mr. HECHLER. Thank you.

Mr. ELMS. In this jet transport program, ERC is concentrating on guidance, navigation, and fully automatic control provided by onboard digital computers. The computers will also generate displays for presenting information to the crew.

Other NASA centers complement this ERC approach by placing greater emphasis on crew operations. So far as displays and controls are concerned, ERC is principally concerned about mechanizations behind the panel; in short, with how you get the information to the crew. The other centers are more concerned with display formats and with the crew's interactions with the system. Ames Research Center, for example, is equipped with flight simulators and is performing research to optimize the role of the pilot in approach landing systems, including the new automatic ones.

The ERC program in V/STOL guidance, navigation and flight control described in the hearings last fall is to provide the technology needed for operating commercial V/STOL aircraft in the terminal area under all weather conditions. As a memory refresher, Mr. Hechler, this is the one where we are using Gemini equipment and techniques designed for the LM lunar landing to get a handle on the V/STOL guidance problem.

Mr. HECHLER. You are going to describe what the current status is, aren't you?

Mr. ELMS. Yes, I will.

The phase one flight test, which was the test to use a guidance system only, is essentially complete. What this demonstrated is that you can produce better results by putting two systems together than by either one of them alone. To go a little bit further into that—because of the physics and mathematics involved, one system has a certain type of error that occurs at a certain rate, and another system has another type of error that occurs at a different rate. By putting these two together, it is kind of like lifting yourself up by your own bootstraps. You do end up with a combined system that is better than either individual one.

The phase one equipment was used to investigate the V/STOL guidance problem in connection with a ground-based radar. The resulting data involves the accuracy of the inertial guidance system versus the number of updates by radar from the ground, and the accuracy of the landing point which results.

This system has recently been installed in a Langley Research Center helicopter. It will continue to be used by them as an important

part of their research program in V/STOL. In their case, however, they are concerned with the stability and control and handling characteristics of the airplane.

The next phase of this program, which is about to begin, introduces additional equipment to take the next step toward a fully automatic guidance, navigation, and flight control system. The phase two system utilizes a state-of-the-art digital computer with a capability for coupling with ILS, radar, VORTAC, and systems like loran and Decca. In other words, it will couple into whatever ground based equipment is available in the FAA system. This experimental system will be evaluated both in the terminal area phase and the landing phase. Until now, we have been concentrating on the landing phase only. This new system will also be used in the terminal area phase. In addition, the phase two system will provide a test bed for flight research on various subsystems and components. For example, we will be flight testing strapdown gyros and laser gyros as a substitute for conventional gyros. If you will recall, last year I emphasized that we had no intention of ever recommending using a design as expensive as the Gemini inertial system. We were using it as a test vehicle only. But the devices I am referring to now are devices which, if proven feasible, would lower the cost of an equivalent system.

Mr. HECHLER. How expensive is that laser gyro?

Mr. ELMS. I am afraid that I could only give a meaningless answer. It is in the research phase now. You will hear optimists talking in terms of a few hundred dollars, but it will be a long time before you can make them reliable and inexpensive. They are still very much in the development phase.

Another device that we are looking at at ERC along this line is an air speed sensor that operates at extremely low speeds. This has been one of the problems. When you slow down enough in a VTOL aircraft, the conventional air speed indicator, of course, is valueless. When you are trying to measure 2 or 3 miles an hour air speed, you need a new device. We have a prototype sensor that has been wind-tunnel tested, and so far it looks pretty good. It has a threshold of only three-tenths of a foot per second.

Turning to collision avoidance—the FAA air traffic control system provides separation between aircraft. However, when visual flight conditions exist, some aircraft are not under positive control. Rules for VFR flight are designed to minimize the risk of collision. However, it is recognized, and has been pointed out, that there are circumstances where additional aid in the form of airborne equipment would be highly desirable.

At last year's hearings, I described the ERC program to develop a pilot warning indicator device. This system will alert the pilot and direct his attention to nearby aircraft. The operation of the pilot warning indicator is in principle very simple. Every aircraft would be required to carry a high-intensity xenon light. This light emits, as we know, a highly visible flash which is readily observabe by the pilot of another aircraft once his attention is drawn to it. These lights simultaneously emit an invisible pulse of infrared radiation which can be detected by a sensitive silicon detector mounted in the other aircraft. The idea has been endorsed by the FAA/COPAG committee who believe it can be of great importance in reducing near-miss situations and the possibility of in-flight collisions in VFR weather.

Simulator studies have been made at ERC which show that the most important zone that should be monitored by such a system is that portion of the forward hemisphere within plus or minus 10 degrees of the horizon. Using one silicon detector for a solid angle of 20 degrees, this would require nine detectors in total. Approximate cost estimates indicate that this type of detection unit, including a display, would cost in the range of five hundred to a thousand dollars in production, thereby placing it within reasonable range for general aviation.

ERC has conducted a competition and awarded a contract for the development of a flight test detector based on these COPAG specifications. The first unit will be delivered this month. After a series of laboratory tests, the unit will be flight tested to provide experimental performance data. The flight tests will be made during the spring of 1970 at Wallops Station, Va., where precision tracking radar and data reduction facilities are available, and where we did our work on the V/STOL guidance system.

Mr. GOLDWATER. How will this be displayed in the cockpit? What will it do?

Mr. ELMS. I want to answer that as thoroughly as I can. At the moment, this is a research program, and the main thing we want to find out in this first phase of the program is, does the thing work? There are several ideas on how to display it. The particular one which will be in the first flight test is a combination of an aural alarm that goes blap and tells you to look, and nine lights. If the light in the center comes on, it means to look out in a 20° cone straight ahead of you; in other words plus or minus 10° up and down, and plus or minus 10° sideways. If the second light to the right comes on, it says to look out to the right 20° and look plus or minus 10° sideways from there, and plus or minus 10° up and down.

Now, it is important to say that this is a research program. This is not a flyoff of a single design for pilot evaluation. It is simply one way of doing it. If we discover that it would be better to have two rows of lights and cover more altitude, then we would make a modification later on in the flight test program.

Mr. GOLDWATER. But it would indicate the quarters.

Mr. ELMS. Yes. It would say, "look here or look there." I will come back and talk a little bit more about it.

Mr. HECHLER. Mr. Elms, could you identify what COPAG is?

Mr. ELMS. I have a little trouble with that myself. But I did ask. It stands for Collision Prevention Advisory Group. It consists of people from ALPA, industry, AOPA, FAA. It is an ad hoc group. I might ask Bill Harper who is present. Does it have an official designation, beyond that?

Mr. HARPER. I believe it was officially organized by the FAA about 10 years ago.

Mr. ELMS. At any rate, it is a place where people from the various interested organizations have an opportunity to go and discuss the subject, at least. We don't get direction from them, but we feel that their opinions are well worth listening to. For example, the specification they came up with is that this device ought to work at least 3 miles in haze and smoke.

Mr. GOLDWATER. This system was born out of the space effort, as I have heard, and it has only been under development for over a year

as I understand it. Why is this taking so long to become a reality? Because there has been a lot of talk about it.

Mr. ELMS. Right. Let me pause and answer that as thoroughly as I can.

In the first place, the basic idea that a xenon lamp has these sensitive lines at nine-tenths of a micron or so, in addition to the visible flash, and the fact that you can detect it with a silicon detector came up in the lab over a year ago.

To reduce this idea to flight-worthy hardware has turned out to take about a year. Now, I am quite frank to tell you that I am as impatient as you are. I wish it had taken less time.

As a matter of fact, very recently—I certainly don't want to turn this into something dramatically wrong but, because of the increasing interest that has been expressed from outside, and the increasing interest we have ourselves—we have taken some action in the last 2 or 3 months to move this activity out of the general research atmosphere, which should be maintained at ERC, and established a specific program office. We put a program manager in charge of it, whose interests are less in research and more in "let's get flying."

I feel like the man who is told to come back with his shield or on it. If I sit here next year and tell you that we have not flown it yet, I'll be on my shield.

Mr. GOLDWATER. Do you have any predictions when this would be available to general aviation?

Mr. ELMS. I will answer that, but before I do, let me tell you what I think is even more exciting. While we have been proceeding from the research area to get some hardware to test out this basic idea, some of us—and I am one of them—have been increasingly concerned with the following question, which I would kind of like to share with you as a pilot. Supposing we got the thing working just as I described. It tells you to look here and look there and look here again. Suppose you're flying from Burbank to Long Beach, which I understand you described the other day. How many times would the alarm go off? It is possible that you might say, well, that's a great device, but can't those people at ERC sort it out a little bit, and tell me which ones represent some kind of a threat to me?

There are precise scientific ways of determining whether two things will run into each other, and if you have a radar set, a relatively expensive device, it is easy to instrument it so it will do this. I have have been worrying about this for a couple of years, and only recently have I been encouraged to think that we may, without too much expense, be able to add to this device the capability to filter out a great many of what you and I would call false alarms.

Now, that, to me, is a very exciting thing, because what I have been worried about is that we might get this thing working, and then go through the pilot evaluation phase, and you know what would happen. Some pilots would say it's great, and others would say it goes off too often, and I'm confused. We might then have a situation where we have the basic technology worked out, but still have a people problem. One group of people might say this is fine. Someone else might say it isn't worth $1,000 to require me to have this system, because it makes me so nervous I'd turn it off.

I am giving a long answer to your question. What I am really interested in is getting a flight test underway in the next few months, showing the basic idea works, and introducing this next phase as early as possible.

It is so new I can't quite tell you. Maybe I'll write you a letter in a month or so and give you the answer to that. But I think we want to get into the second phase of the thing as soon as possible.

Now, how long would it be until it is available to general aviation? This was your original question. I wanted to give you all this background first. It is always several years to get from feasibility to operation.

But while I'm at it, I might emphasize what I said at the start. Our role is not to develop a specific system. Our role is not to become involved in regulations, in other words in the FAA's business. Our role is to demonstrate feasibility. So in a way, I could duck the question by saying, I don't know, because it is not my business. But what you want to know is when is it possible for you to look at it in an experimental way and say, this is a good system, I'd say within a couple of years.

Mr. GOLDWATER. Is industry working along with you on this?

Mr. ELMS. Yes, they are. As a matter of fact, after we let this competitive contract, two other companies decided to build similar equipment, using their own resources. One of them will be delivered simultaneously or in the same time period with the one whose development we paid for.

I have talked to the chief executives of these companies. They realize how important this thing is. I think the same thing happened within these companies that happened to us. Namely, instead of this being a research idea, they plan to accelerate it and see how fast they can go.

Mr. HECHLER. While we are on this subject—and it is a fascinating one—what are the relative expense factors involved here of the xenon light and the silicon detector?

Mr. ELMS. The xenon light costs in the order of $100 each, at the moment.

Mr. HECHLER. Well, this committee can't overemphasize the importance of this, and we applaud you for your efforts. And I just want to ask one further question.

To what extent is FAA working with you on this development?

Mr. ELMS. Well, we have a joint committee. Now, you have heard a lot about a committee that is studying what we are supposed to do in the future. We have a little committee you may not have heard of, and I don't know what the name of it is.

But I have a couple of people on it including Bob Wedan, and the FAA has Blatt, Weber, and Connerly.

Mr. HECHLER. You call it Elmscom?

Mr. ELMS. No. This isn't just ERC. It is a committee involving the current activities of FAA and NASA. In fact, they're meeting this afternoon.

It is significant to me that of the six items that they are discussing, we are involved in three of them. I would say in answer to your question that the FAA spends more time on things where they think they are going to make an immediate contribution, such as in the V/STOL

area and the blind landing system I described for conventional aircraft, and so forth. I think that FAA participation will be much greater when we get to the point that I was describing to Mr. Goldwater, where there is something to fly.

Mr. HECHLER. You may continue.

Mr. ELMS. Well, let me talk for a moment about another program at ERC related to collision avoidance. This is an electromechanical heads-up attitude indicator. This device places a rod between the pilot and the windshield, where the rod maintains an alignment with the horizon as the aircraft pitches and rolls. This is like an artificial horizon, only it is a rod up there, in front of your eyes, between you and the windshield. Consequently, it serves to move the pilot's eyes from the cockpit to the outside scene, where he can then be more alert to collision hazards.

A principal advantage of this device over the more conventional optical projection schemes is the very much lower cost. The first thing one thinks about is projecting an artifiicial horizon on the windscreen but it is astounding how much it costs to do something that sounds that easy.

Our device is controlled by the aircraft's vertical gyro through a simple servocontrol system. It is a very simple device, and this is one idea we moved fast on, because it didn't require anything more than just putting some things together in our own machine shop. A variety of pilots have said they prefer this type of indicator, because instead of looking at an artifiicial horizon, you look at something in the cockpit ahead of you which in fact, simulates the horizon.

In cases of partial VFR, in haze and smoke, you are looking at the rod moving around. When the smoke goes away, you see the rod coinciding with the horizon. So it is a simple gadget, and it can be inexpensive.

As far as when this could be available to general aviation, it is available now. It is just a matter of generating some interest. Some manufacturers are looking into it. Again, it is not our business to push it any further. We have demonstrated that it works.

Now for a different subject. NASA's research in the use of satellites for navigation and air traffic control and surveillance was briefly mentioned last year. A program is evolving. Two NASA centers are involved, the Goddard Space Flight Center and ERC. Goddard has the primary development responsibility, because of their vast experience of course in satellites. Our involvement is based on our earlier work in systems analysis of such a device, which I described last year, involving studies of orbits, ranging measurements for positions, and methods of modulating for voice and data communications. At this point at ERC, we are shifting emphasis from definition studies to development of instrumentation. These require laboratory and field testing for performance measurements. One development that has reached the hardware stage—the experimental flight test hardware stage—is an L-band receiver. The L-band, sometimes called UHF, is a serious candidate for the operating frequency range of the system. I will interject that the reason for this is that the bands that we are using now are getting so cluttered, you have to think about going somewhere else, and the L-band is an open area. However, the lack of data involving the use of this frequency for this type of applica-

tion requires further tests. And in these tests, we must examine background noise, multipath measurements, and ranging accuracy.

We had hoped to obtain these data with the aid of an FAA aircraft, working with the ATS–E satellite. The ATS–E satellite failed to stabilize after its launch last August. ERC has generated a substitute program using high altitude aircraft to simulate the spacecraft. This program will provide us with a limited amount of data to work with until the ATS–F is launched.

There are other NASA avionics programs, and I will discuss them briefly. These include fly-by-wire systems—which, incidentally, I know Mr. Kirschner discussed as an important aspect of V/STOL—detection of clear air turbulence, and the application of biotechnology to aeronautics.

If we look at the control systems of large aircraft, like the jumbo jets and the SST, the advantages of fly-by-wire systems to replace mechanical control systems become apparent. The mechanical control systems are exceedingly heavy devices. In a fly-by-wire system, electrical sensors are attached to the pilot controls. They are connected electronically to the aircraft control surface actuator. Pilot-induced motions of the control wheel therefore cause the control surfaces to move without any direct mechanical connections. As I said, mechanical systems characteristically are heavy and have high friction forces for a larger aircraft.

The potential advantages of substituting electrical or fly-by-wire systems for the mechanical designs are clear. However, concern regarding their reliability is limiting their use. Therefore, ERC is concentrating on design techniques to achieve highly reliable fly-by-wire systems. The reliability goal should be as high as that of the primary structure of the aircraft.

I might add, after we achieve this objective, we are going to have a hard time convincing people, because people just don't like the idea of not being connected mechanically to the control surfaces that are moved. So first we have to be sufficiently sure that we're right, and then we are going to have a problem convincing people. At least someone is going to have a problem.

Well, anyway, how do we do this? We consider the prime power generation and distribution, power interruptions for any reason, including such things as lightning strikes, which were brought to our attention recently, multiplexing techniques, redundancy in sensing, signal transmission and actuation, and ground checkout.

As I mentioned much earlier, we at ERC are working on navigation for commercial airliners in the terminal area. In addition to this, Langley Research Center is investigating several terminal area radio navigation techniques for general aviation, with the intent of applying techniques developed in the space program wherever possible.

Now a very different subject that has become very important in the last year is the consideration of the expense of flight testing in order to prove the feasibility of the ideas we are generating. Before flying anything, one should go through a period of analysis and laboratory tests. You might as well find as many problems as possible on the ground, because it is so much more expensive to perform flight tests. We are discovering that a very important part of this ground testing requires simulating the environment of the flight system by the use

of laboratory computers. This step can be compared to the use of wind tunnels for evaluating aircraft performance.

We now know how important wind tunnels are. I imagine some people back in 1916 wondered why we spent all that money for wind tunnels. Why didn't you just go up and fly it and see how it works? We are in that phase now. Some people say, are you very sure you want a big simulator to simulate the air traffic control system; in other words to simulate the avionics environment? Are you really sure you want to do that?

And I have a feeling—I am going to be a prophet here—I have a feeling that this is somewhat like saying, in the old days, "Well, why bother testing this little model in a wind tunnel? Why don't you just go up and fly a real airplane and see how it performs?"

I think there is a lot of money to be saved by looking at avionics as such an important function that you can put it in a simulated environment and test it on the ground, instead of saying that avionics are little black boxes that you buy at the store and install them in an airplane—which is, of course, the way we did it years ago.

Another field of interest to practically everybody is clear air turbulence. There is a national clear air turbulence committee, with participation by many groups.

I will mention the clear air turbulence activity of my fellow center first. Langley Research Center is conducting experiments using laser technology to detect clear air turbulence. It is a fascinating thought, but it is not quite ready for flight test. As you know, this involves using a laser like a radar set. You bounce the laser beam off something, and then measure the echo. The ground tests are very interesting, and I am sure they will get into flight testing ultimately with this device.

We at ERC have a more conventional device which measures atmospheric temperature. This is a radiometer. A radiometer is half a radar set. It is the part of the radar set that receives. We have developed radiometers for many, many years, and for many uses, but this is sort of a new way to use a radiometer—to look forward as far as a hundred and twenty miles, measure temperature differences, and then try to correlate these temperature differences with clear air turbulence. Two of these radiometers have been built at ERC. We have subjected them to environmental tests. They are ready to fly. There is an RB-57-B which will be available at the Flight Research Center early in 1970, perhaps as early as January, which will be used to flight test this device.

One of the basic unknowns that must be resolved is the relationship between the quantity measured and the existence of clear air turbulence. As I said, the ERC radiometers will measure temperature fluctuations. But the question remains, just how good is the correlation between temperature fluctuations and turbulence? We think it is good, but we haven't measured it. Flight tests with the ERC system will provide data on this question for millimeter wave lengths. The Langley tests will do the same for the visible spectrum.

I think I should add here, before someone asks me, who else is working on this problem. There is quite a lot of activity. The Boeing people have been pursuing a program using conventional radar. The Canadian Government has also been sponsoring tests using radar. There is a system developed by one of the aerospace companies on the west coast

which functions somewhat like ours, except it uses infrared, whereas we are in the microwave frequencies.

Now for a few words about physiological monitoring. Aeronautics, and high-speed flight in particular, often result in high-stress levels. Because of this, interest exists for monitoring pilot, crew and ground controller performance, and the so-called man-machine interface during occasions of stress. Such monitoring should furthermore be nonencumbering, noninvasive, atraumatic, and it should also measure mental alertness.

When I say atraumatic, I mean nontroublesome sensors. One of the things that I am sure you have heard enough about is that it is difficult to do your job with too many things attached or implanted. These attached devices do affect your stress levels. So it is extremely important to work in this area of atraumatic or nonconnected devices. Last year our statement described the remote oculometer being developed by ERC. This is an electro-optical instrument which measures eye-pointing direction, pupil position, pupil diameter and blink occurrence. The feasibility of the remote oculometer has now been successfully demonstrated. The indications are that this instrument can contribute to flight safety, to more efficient cockpit layout, to phychological performance monitoring, and as a training device or simulator.

The FAA has, for example, ordered a head-mounted oculometer to determine where pilots are looking outside of the aircraft. The Department of Defense is also interested in using the oculometer for real-time target designations. We are presently working in connection with the Langley Research Center toward applying the oculometer to aircraft simulators and to aircraft man-machine interface studies.

An interjection here, in the past, when you put a pilot in a cockpit simulator, he writes a report later. He might say, for instance, "I found the thing kind of busy, and I had to look around a lot." This is a subjective type of evaluation.

With the oculometer we have an objective report on how much he looks around, and where he was looking. If his eyes are frequently going from here to here and back again, you get a clue that maybe those two instruments ought to be a little closer together.

One more subject. A NASA intercenter program of research in the high-speed flight regime is based on the recent acquisition of the YF-12. We will use the FY-12 to investigate problems of flight path management considering the interactions of the pilot, flight control system, displays, and the ATC. Examples include altitude hold under maximum performance conditions, procedural techniques for climbout, cruise, and descent to optimize performance. These are important, among other things, because of the SST development.

In addition we will use the YF-12 to conduct research on electronic components and subsystems of the satellite-based navigation and traffic control system, which I told you about earlier. Specific tests will include environmental effects on L-band antennas and receivers, assessment of position determination capability of the satellite navigation system, and another handle on the multipath problem, which we had hoped to get at by now.

The electronics research program indicated here represents only a portion of the total planned YF-12 program. Other centers are involved in investigations or tests on structures and flight loads, aero-

elastic effects on stability and control, aircraft dynamic and aerodynamic characteristics, engine-inlet research, handling qualities, et cetera.

I have attempted to describe some of the ways NASA provides electronics support to aviation by detailing work at ERC and at other NASA centers. Much of this work is a direct outgrowth of NASA's long-established aircraft vehicle research program.

Other research more closely supports the operation of an aircraft in an ATC environment, or ATC-related research. I have also attempted to describe, by example, our increasingly productive relationships with the FAA in these latter ar as.

We are convinced that the research needs of the aviation industry can only be met by an overall research approach to both aircraft problems and to the systems problems inherent in operating the aircraft in a real world environment.

Mr. HECHLER. We appreciate very much this description of ERC's activities and contributions. In addition to the things you have highlighted, you have contributed to our vocabulary, also.

Mr. Helstoski.

Mr. HELSTOSKI. No questions.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. I was interested in this.

You were talking about this fly-by-wire concept.

Mr. ELMS. Yes, sir.

Mr. GOLDWATER. This is, I take it, an entirely electrical system?

Mr. ELMS. Yes, sir. Let me say two things about it. Our early astronauts, all of whom are friends of mine, I think would allow me to say that they not only were pilots, but they were pilots' pilots. And when they started the space program, they came equipped with the background of pilots; and the firm opinion of pilots; and I am sure that not a one of them liked the idea of fly-by-wire when they first heard about it; and now I think they all like it. We had a fly-by-wire system for sure in all its glory in the Gemini program, and we of course have it in the Apollo program.

We can consider saving weight in the supersonic transports where it is extremely important in terms of the pounds per dollar, and how many people you can take to Europe and so forth. But—and this gets to a point that I have made when I talked to the bankers association—some say, why on earth do you spend all this money in space? This is an example of the benefit that results from the fact that in space you have an absolute requirement to do something despite certain limitations. We didn't have boosters big enough to lift a spacecraft big enough to carry heavy control systems, so we were forced to look harder at some of the things that are technically feasible, but require a great deal of effort. So when we talk about fly-by-wire, we are talking about something that has happened. It has happened in space. This is the first time I've thought of it, since you've asked me the question, but this is a space application. We usually think of applying things like the Gemini guidance system.

The astronauts lives certainly depended on that fly-by-wire system, just as will be the case in an airplane. We were faced with this requirement; we were forced into it, and we did a good job. We never had any

trouble with it and therefore we are confident that something can be done to apply what we learned to aircraft.

The basic system, Mr. Goldwater, involves the technique of connecting the pilot's controls to the control surfaces by electrical means. There is another aspect to the problem—"stability augmentation." As you go from little simple airplanes to big ones like the supersonic transport, you get yourself into a situation where you can make a more efficient airplane, providing you are willing to put up with some "instability."

I am not an aerodynamicist, and I am not going to get in the business, but if you decrease the stability of an airplane, you can get some gains in performance. Now, if you already have a fly-by-wire system working, we electronics people would love to put a little black box between this input and that output to make up for this instability at a great saving in weight.

What I am trying to say is stability augmentation, which can cut a tremendous amount of weight out of an airplane, and fly-by-wire are first cousins. In fact, they're the kind of first cousins that ought to get married.

Mr. GOLDWATER. I have seen the hydraulic mechanisms for, say, an F4, and they are quite sizable and weigh a great deal. Is this supposed to replace this?

Mr. ELMS. I am not exactly familiar with that thing, but I think the quick answer would be no. You have finally got to have the muscle, in other words, the actuator.

Mr. GOLDWATER. I see.

Mr. ELMS. It is how do you get from one end to the other.

Mr. GOLDWATER. The control goes back to the tail surface?

Mr. ELMS. On the other hand, that was a very quick answer. I know of another experimental system, where hydraulic actuators are used to actually provide some of the redundancy required for safety. In those cases you definitely can improve the situation with electronics.

Mr. GOLDWATER. What you are talking about is going from the controls where your hands are, to the tail, by electronics?

Mr. ELMS. Yes.

Mr. GOLDWATER. Instead of wire.

Mr. ELMS. Yes. What you have now is a cable that goes back and opens a valve and lets hydraulic fluid in. If that is all there were to it, just a cable from here to here, then you are not saving very much.

When you start putting in the redundant systems for the things that happen, the way you get around a failure of a hydraulic cylinder, and so forth, you then start seeing an addition of weight, which could be helped by the fly-by-wire system. If you look at a big system, you will find some hydraulic actuators doing what you think they ought to be doing. Then you will find some others, and you have to puzzle out what they are doing. Well, they are there to operate in the event that another one fails, in a certain way. And when you come to this redundancy in safety features, that is where I believe ultimately we will be able to save weight.

Mr. GOLDWATER. I certainly enjoyed your testimony. What you are doing is certainly very exciting. You talk about things of the future that people can understand. I enjoyed it.

Mr. ELMS. Thank you very much.

Mr. HECHLER. Mr. Wydler.

Mr. WYDLER. Mr. Elms, we have been interested in the question of steep descent by aircraft into airfields, mainly from the point of view of being a noise abatement procedure, and it seems to me it was something that was very close to being within the state of the art, right now, of accomplishment.

I have been told in the last few years, and even received a letter today which I couldn't fully understand, indicating that there were some technical problems in this regard that still needed solution before it could be done.

Is the Electronics Research Center charged with the development of any equipment with procedures in regard to the steep descent landing problem at the present time?

Mr. ELMS. We do not have a specific assignment on steep descent. However, in the programs which I have been describing that started with the V/STOL program, the V/STOL guidance and landing program, the conventional jet landing program, and so forth—we are getting at the very basics of how do you provide a pilot with information so he can fly an unusual path—steep descent is one form of unusual path.

Mr. WYDLER. Excuse me. But why would you describe it as unusual? Because is not this being done now?

Mr. ELMS. That's right. Just like V/STOL is unusual, compared with an ordinary aircraft. But although we started with the V/STOL, we then got ourselves into a conventional approach and landing program, and then into unconventional approaches such as leading people into the airport in a curved path.

So I guess the answer to your question is the work that we are doing, as far as guidance and navigation along a specific path to a specific point can be used as basic data input into the steep descent problem.

Mr. WYDLER. But that doesn't seem to me, as a nontechnician, to be really the problems that they are worried about.

They talk more about the problems being one of the pilot being able to get his aircraft out of the descent path at any point, and they want lift controls and improvements and so on and so forth. But I don't understand all the jargon. But that seems to be the question that is raised. They seem to have passed by these other questions.

Mr. ELMS. Let me make a couple of statements here. The first thing I want to tell you is I am not an expert in this area.

Mr. WYLDER. I am just interested now in what you may be charged with doing on these problems.

Mr. ELMS. Well, we are charged with working on the general problem of providing guidance and navigation for any kind of flight path.

Now, I am not an expert in what the limiting factors are in the steep descent, whether the limiting factors are people problems, or getting people to get used to it; whether there are problems of reliability; or whether they are problems that I don't understand. I am not sure.

You know, I have been reading what has gone on here, and I read some of the earlier questions you asked, Mr. Wydler. Maybe I can leave it like this: When I read some of your earlier questions, I said to myself, when I have some time I am going to find out more about this. So that is the best I can say. I am not an expert in it.

Mr. WYDLER. But you can assure me that the limit of what you have been charged to do is along the lines of what you testified here.

Mr. ELMS. It includes work which could be applied to that area, as far as I know. And I am a layman in the area. I am going to look into it.

Mr. WYDLER. Mr. Chairman, would you give me permission to just digress for about 2 minutes with Mr. Elms? I would just like to get a little bit of an idea where they are at ERC in construction.

Mr. HECHLER. Providing you don't ask him where the New York airport ought to be located.

Mr. WYDLER. No, I won't ask him that.

Would you please tell me how you are doing up at ERC with your construction progress?

Mr. ELMS. Yes. It is more fun every year. Two years ago we had to say why we hadn't done anything yet; last year we said we were going to do something; and this year we can fortunately say we have done it.

We are moving into the center. We have, as you know, over $26 million worth of buildings—the 14-story central laboratory building, the auditorium, the guidance laboratory—which is a unique facility—and the optics laboratory. People are beginning to move in. We will be in and working by around March.

Mr. WYDLER. Thank you.

Thank you, Mr. Chairman.

Mr. HECHLER. Thank you, Mr. Wydler.

One final question in addition to what you discussed about fly-by-wire. What are you doing in the area of developing power systems? And is there a possibility of a breakthrough in this area?

Mr. ELMS. Mr. Hechler, by "power systems," you mean electric power systems?

Mr. HECHLER. Yes.

Mr. ELMS. We are involved—and other centers are, also—in taking a new look at electrical power.

We traditionally have had low-voltage direct-current systems and 400-cycle alternating-current systems. We are looking at the use of higher frequency alternating current and higher voltage direct current and the kind of distribution and utilization equipment that can handle it. It is now in the research stage. The research experts are tremendously enthusiastic about the saving in weight and the increased reliability that you can get by using advanced electrical systems. It is very exciting, but there is a lot of work to do before people are going to change to a radically different electrical system. There is great promise, but it is still in the research stage.

You know, we talked last year about the difficulties in directing research. If you get too enthusiastic, and say we're going to do something a year from now, you may push an idea into development too fast. But if you are too relaxed, it may never happen.

As we discussed last year the problem is how to keep in the middle. I hope we are doing so in this electrical area.

Mr. HECHLER. Well, thank you very much, Mr. Elms. You have been very helpful this morning.

Mr. ELMS. Thank you.

Mr. HECHLER. I am pleased to welcome to the committee Dr. John S. Foster, Jr., the Director of Defense Research and Engineering.

Dr. Foster, it is a pleasure to have you before the committee, and if you have a prepared statement, you may proceed.

Dr. FOSTER. Thank you very much, Mr. Chairman.

STATEMENT OF DR. JOHN S. FOSTER, JR., DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

Mr. Chairman and members of the subcommittee, it is a pleasure to appear today before this distinguished subcommittee to talk about aeronautical research and development. This is a most important series of hearings, for the problems and opportunities of aeronautical research and development are national in scope, they are both public and private, they relate both to war and to peace, and they are shared by three major parts of the Federal Government.

It is essential that aeronautical research and development be a nationally coordinated program and that this subcommittee continue to provide overall national insight and leadership. We who have responsibility for this work in the Department of Defense want to take every opportunity to coordinate it with this subcommittee.

I will start with a broad overview of the status of aeronautics today in the Defense Department. include the lessons from the war in Southeast Asia, describe some of our near-term research and development, and, finally, make some specific proposals for the future. Dr. Seamans will present a detailed description of Air Force programs, policies, and needs.

You will note from our two presentations that the importance of aircraft and aeronautical research and development is not diminishing. On the contrary, the services are depending more and more on aircraft to help meet the many and varied defense responsibilities assigned to them.

The harsh war in Southeast Asia has provided an object lesson in the continuing need for a broad and advanced aeronautics program. Aviation has assumed an unprecedented share of the logistics burden. New basic mobility has been provided through the air. Close air support has risen to a new level of effectiveness.

The foot soldier and marine are still our ultimate weapons, but they cannot reach the conflict and cannot be sustained and protected through the fight without aircraft. Historians may well conclude that the tide of defeat was turned in 1965 by the timely arrival in Southeast Asia of American airlift, tactical air, and new technology.

The importance of aviation in the defense of our country's interests will continue to grow. We entered the war in Southeast Asia basically well prepared for air operations. The aircraft were there when they were needed. Technology had done its job. A generation of toilers in aviation research and development had done well in the Department of Defense, in the services, in the National Aeronautics and Space Administration, in the Congress, and in industry.

Prewar research and development paid off most conspicuously in air mobility for ground soldiers. Practical visionaries in the Marine Corps and Army had completed the tedious research and development work which resulted in air-mobile units for the Army and vertical envelopment in the Marine Corps. The helicopter and new techniques for its use changed the nature of ground warfare.

Close-support weapons and doctrine had also made great strides. The new A–7, the older A–1's and B–52's, and even the old C–47 armed with the most advanced technology demonstrated the soundness of national aeronautical research and development.

This war, like others, posed some new problems which needed new solutions. For instance, we solved some of the problems of finding targets at night, in bad weather, and in jungle areas—but available technology in this area proved to be insufficient.

We must do more. We need to improve the accuracy of air-delivered, high-explosive ordnance. The defense community was too slow in changing its thinking from delivery accuracies sufficient for nuclear war to the accuracies required for conventional war.

The experience of this war has taught us again to value highly the survivability of aircraft. We need tougher aircraft; we need greater maneuverability against surface-to-air missiles, against enemy aircraft, and against conventional ground defenses. We still need guns on aircraft—and better guns.

We are applying the lessons of the war to new development programs. The coming aircraft will be tougher, more maneuverable, and better armed. They include:

- The F–14, an advanced carrier-based fleet air defense fighter, which entered the development phase in February of this year.
- The F–15, a land-based Air Force air superiority fighter with special emphasis on maneuverability, for which completion of source selection is scheduled by the end of this year.
- The S–3A, a carrier-based antisubmarine warfare aircraft of advanced design, this year.
- The AX, a less expensive, large payload, close support aircraft for the Air Force.
- The B–1, a long-range nuclear-war bomber, which is being designed also for conventional war.
- And AWACS, an airborne warning and control aircraft.

We are exploring other needed types of aircraft:

- HLH, a heavy-lift helicopter which would substantially lessen our need for a foreign base structure in any future conflict.
- LIT, a light intratheater transport to take over from the C–123 and C–7 which have served so well in Southeast Asia.
- And V/STOL, an important concept which will require extensive research and development but which could pay off handsomely in defense. Our joint operational experience with this type of aircraft will be obtained from the 12 Harriers that the Marines are acquiring from the United Kingdom.

These and other necessary research and development programs can be successful only to the extent that they are able to build on a broad and solid technological base. This base has been adequate in the past to meet most of our military aviation needs, but we should all be concerned about the future. We have used up much of the base that was built in the post-World War II years, and we must turn to the job of building it again.

It is a national effort that is required. The Department of Defense can be a specialized contributor, but it should not be responsible for establishing the Nation's technology base. In the Federal Government, development of the aviation technology base is the primary responsibility of the National Aeronautics and Space Administration.

Mr. HECHLER. Dr. Foster, just a minute. Off the record.

(Discussion off the record.)

Mr. HECHLER. Off the record again. You may continue.

Dr. FOSTER. Certainly, sir.

As has been made clear by the testimony of Dr. Paine and his colleague during this series of hearings, the NASA leaders welcome this responsibility and are increasing their efforts to fulfill it. We in Defense and those in industry must do more also.

It will not be easy to rebuild our technology base in aeronautics. There are two complicating factors. One, of course, is the war, which has led us to consume the technology base at an abnormally high rate. The other and more serious complication lies in recent history. It started with the challenge of sputnik to this country's civilian and military technology. Sputnik showed that the Soviet Union, behind a veil of secrecy, had taken such a leap forward in space and booster technology that it could have become the dominant nation both in peaceful uses of space and in military applications of rocketry.

The challenge, as you all know, was met—but at a price. In order to win the peace race and to install an effective deterrent missile force in time, we as a nation had to set new priorities. We moved scientific and engineering talent out of aeronautics and into rockets.

Today, we must continue to maintain our position in missiles and space, but we also must reemphasize aeronautics. The interesting new aircraft projects will attract some of the necessary talent to aeronautics, but industry and the Government still face a shortage of skilled manpower.

From the viewpoint of a user agency, the aviation technology base that does exist is not as usable in the aggregate as it would seem. We are relying heavily on industry's contributions, and the major companies and the many subcontractors are working on important new aircraft—the giant transports, the SST, and new types of military aircraft.

But these great programs are so involved and risky and require so much management and engineering attention that contributions to the technology base tend to be neglected. The technical progress that does exist tends to be scattered and compartmented in individual companies.

I believe this is a problem of national scope—one that requires national support, national coordination and, equally important, national awareness. The solution to this problem lies in coordination and leadership within the executive branch.

NASA, of course, is the Government agency primarily responsible for aeronautical research in the United States. Substantially more efficient and timely use of available resources could be made if NASA were to coordinate overall research programs more closely in the interests of all users.

DOD relations with NASA continue to be sound. NASA people participate in DOD technical and advisory groups, and DOD assists NASA similarly. Currently the NASA Research and Technology Advisory Committee on Aeronautics, which provides technical and policy guidance to NASA in the field of aeronautics, has a member from each of the military services and a member from my staff.

DOD benefits from NASA's research and development go beyond the use of NASA's research data. Upon request, NASA will perform research tasks on particular problems either, jointly with DOD elements or separately. Assistance between DOD and NASA is not a one-way street. The DOD loans or transfers to NASA aircraft such as the F-106 and F-111A for use in research programs.

A recent joint solution to a development program is the Army-NASA facility-sharing program. NASA has facilities developed over the years for aeronautical research but lacks the technical manpower to utilize them fully. The Army lacks an adequate in-house technological and development capability.

The Army-NASA plan will increase in-house capabilities for aviation research and exploratory development by the addition of some 175 uniformed and civilian Army specialists to the resources of Ames, Lewis, and Langley Research Centers. In exchange, the Army will have joint use of the facilities.

Projects are planned in advanced helicopter technology; V/STOL stability, control and handling qualities; and compound helicopter technology. The arrangement should benefit both Army and NASA, and may lead the way to similar agreements with other agencies.

While coordination of aeronautical research programs by NASA is needed nationwide, it is currently done in part on an interagency basis. We in DOD work very closely with other Government agencies such as NASA and the Department of Transportation (DOT) in order to make the most effective use of our national resources.

You know of the efforts of the Aeronautics Panel of the AACB (Aeronautics and Astronautics Coordinating Board) to review and coordinate the programs of NASA and DOD in the aeronautical area. DOT and FAA representatives regularly attend Aeronautics Panel meetings and participate in its activities. We also have a working relationship with the National Aeronautics and Space Council, and it is expected that their staff representatives will also participate in AACB and Aeronautics Panel activities.

The Aeronautics Panel has been most helpful in establishing better understanding and working relationships between the different groups. Resources of the individual agencies have been limited, however, so some joint funding and joint participation have been necessary. Some of these programs are the YF-12 flight testing, the XV-4B VTOL research aircraft, the P-1127, the XC-142, et cetera.

It is the plan of the Panel to go beyond the coordination activity and embrace joint planning of the aeronautical programs. The joint planning will start at sufficiently early stages that the programs are still flexible and changes and integration are still relatively easy to achieve.

Our ability to take advantage of the lessons learned in Southeast Asia and to remain competitive in military aviation depends not just on good management but also on adequate research and development funding as well. So let's talk about funding.

Table I shows the DOD's total obligational authority for aircraft R.D.T. & E. for the last 5 years, plus the current request for fiscal year 1970. The recent authorizations for 1970 have been cut about 12 percent below the requested level. As you can see, the funding was essentially constant through fiscal 1969, while inflation has decreased the amount

of work we were able to do by about 25 percent. We must establish a new upward trend in aeronautical research and development funding.

TABLE I.—*DOD aircraft R.D.T. & E. yearly funding*

Aircraft R.D.T. & E. TOA:	*In millions*
Fiscal year 1965	$1,136
Fiscal year 1966	1,256
Fiscal year 1967	1,199
Fiscal year 1968	1,043
Fiscal year 1969	1,310
Fiscal year 1970 (requested)	1,708

It is my understanding that the Soviet Union has been allocating annual increases of approximately 10 percent per year to all defense-related research and development, while we in the United States have increased ours overall by about 4 percent.

Mr. HECHLER. Excuse me, Dr. Foster. Do you mean all defense-related or aeronautics and aircraft?

Dr. FOSTER. No, Mr. Chairman, I mean all defense-related research and development. That would include activities in the Soviet Union that are similar to the activities in this country of the AEC, NASA, and the Department of Defense.

Mr. HECHLER. This might be a good point to suspend, and the subcommittee has the permission of the House to meet while the House is in session, but we will suspend for about 15 minutes for this quorum call.

(Recess.)

Mr. HECHLER. The committee will be in order.

Dr. Foster, when the quorum bells rang, you were on page 8 of your statement, and had just commented on the question of Soviet expenditures and defense-related research. If there is nothing further on that question, you may proceed.

Dr. FOSTER. Mr. Chairman, I believe as we go to the next paragraph, we will get into that matter more deeply.

Mr. HECHLER. You may proceed.

Dr. FOSTER. The two countries have reached a point at which the total efforts in defense-related research and development are about equal. Unless we take positive action, it is only a matter of time before the U.S.S.R. assumes the lead not only in the level of effort but, shortly thereafter, in technology.

Table II, which shows the latest available figures in round numbers, illustrates this disturbing trend.

TABLE II.—DEFENSE-RELATED R. & D. FUNDING

[In billions of dollars]

	Fiscal years					
	1955	1960	1965	1968	1969	1970
U.S.S.R.	2	5	10	14	15	16
United States	3	7	13	14	14	[1] 14

[1] Requested.

I would like to pause for a moment, Mr. Chairman, here to comment on table II. These are the total defense-related research and development funds being expended in the Soviet Union and the United States.

The table treats the period from 1955 through 1969, and in fiscal 1970 we have the anticipated expenditures for the Soviet Union and the requested number before the Congress for the United States.

Even though aeronautical research is only a part of the overall effort, this subcommittee could make a major contribution by examining the need to maintain aeronautical research and development funding at a high enough level to assure our continued world leadership in the face of a vigorous Soviet effort.

Mr. LUKENS. Mr. Chairman.

Mr. HECHLER. Mr. Lukens.

Mr. LUKENS. Forgive the interruption. I wonder if I could have an explanation on table II. I gather the numbers represent the percentage of the budget.

Dr. FOSTER. No, Mr. Lukens. The numbers are the actual billions of dollars that are involved in the research and development programs in the two countries.

Mr. LUKENS. Thank you.

Dr. FOSTER. We get those totals in past years by adding up the defense-related research in this country by NASA, AEC, and the Department of Defense.

Mr. LUKENS. Thank you. I apologize for the interruption.

Mr. HECHLER. In other words, the percentage would be considerably higher, is that correct? You are giving absolute figures in billions, therefore the conclusion could properly be drawn that the percentage of total GNP, for example, would be higher?

Dr. FOSTER. Yes, sir. We would roughly double that ratio in going from the United States to the Soviet Union, since our GNP is roughly twice theirs.

Mr. HECHLER. Thank you. You may proceed.

Dr. FOSTER. I would like to repeat the sentence, if I may, Mr. Chairman. Even though aeronautical research is only a part of the overall effort, this subcommittee could make a major contribution by examining the need to maintain aeronautical research and development funding at a high enough level to assure our continued world leadership in the face of a vigorous Soviet effort—an effort which has paid off for the Kremlin in the form of impressive new military aircraft.

While we can express our defense needs by a comparison with the potential military threat, it is necessary also to measure our national economic needs and their relation to aeronautical technology. One useful indicator is our balance of trade with the rest of the world. Although overall our balance has been declining, our aerospace industry is doing quite well.

Information provided by the Aerospace Industries Association on the relative contribution of the aerospace industry is presented in table III. These data show a decline between 1967 and 1968 for the total U.S. balance of trade.

For the same period, however, the aerospace balance increased by about 34 percent. Since the aerospace industry's exports of $3,296 million provide almost 10 percent of the total—that is, $36,830 million—U.S. exports, the desirability for maintaining the present health and importance of the aerospace industry is evident.

TABLE III.—TOTAL AND AEROSPACE BALANCE OF TRADE, CALENDAR YEARS 1960 TO DATE

[Dollar figure in millions]

Year	Total trade: Total U.S. trade balance	Total trade: Exports	Total trade: Imports	Aerospace: Trade balance	Aerospace: Exports	Aerospace: Imports	Aerospace trade balance as percent of U.S. total
1960	5,369	20,375	15,014	1,665	1,726	61	31.0
1961	6,096	20,754	14,658	1,501	1,653	152	24.6
1962	5,178	21,431	16,251	1,795	1,923	128	34.7
1963	6,000	23,062	17,001	1,532	1,627	95	25.3
1964	7,556	26,156	18,600	1,518	1,608	90	20.1
1965	5,852	27,135	21,283	1,459	1,618	159	24.9
1966	4,524	29,884	25,360	1,370	1,673	303	30.3
1967	4,409	31,142	26,733	1,961	2,248	287	44.4
1968	1,133	34,199	33,066	2,623	2,995	372	231.5
1969 [1]	1,213	36,830	35,617	2,920	3,296	376	240.7

[1] Estimate.

Note: U.S. balance of trade is the difference between exports of domestic merchandise and imports for consumption.

Sources: U.S. Department of Commerce, Bureau of Census: "U.S. Exports of Domestic Merchandise. Schedule B, Commodity by Country of Destination"; "U.S. Imports of Merchandise for Consumption"; "Highlights of U.S. Export and Trade." (All are monthly publications.)

Nevertheless, as your report on the Paris Air Show stated, we can expect strong foreign efforts to penetrate a significant portion of our world aircraft market. Observers of the Soviet SST, the British-French Concorde, and the multitude of military aircraft prototypes being developed consider them serious threats to our status as world leader in aviation. Because of our dependence on the aerospace industry for a favorable balance of trade, I believe it is essential that we take the necessary steps to insure our continued leadership in aviation.

Some of the future benefits to be derived from a strong technology base in aviation are obvious. Our national defenses and our balance-of-payments position can depend on it. But another real benefit is not as visible. This is the spin-off to the civil sector from a strong military development program. In years past, civil aviation was able to use the entire aircraft as developed for military needs. The relationship today is somewhat different. Whereas entire aircraft used to make the transfer, today various components, subcomponents, structures and techniques are spun off.

The reason is that civil aircraft must now be more specialized for civilian purposes in order to meet the competition. Total benefits to the civilian sector are greater today than in the past, but they are not as easily identified. The aeronautics panel of the AACB is currently helping the Department of Transportation in a study that will help you and others to identify spin-offs from military to civilian aviation.

In summary, Mr. Chairman, we can learn much from experience in Southeast Asia about the importance of aviation technology. We can look abroad and see what our potential military rivals are doing. We can look at the disturbing figures on balance of payments. We can see ways to improve the coordination of a national aeronautical research and development program. But I want to assure you that we in the Department of Defense fully realize that our defense and national requirements in aviation are not our only urgent national needs.

There are other public and private needs that can be met in part by the application of modern technology, and these other needs must have their rightful place on the Nation's priority list. We in aviation

technology can help attain the goals by insuring that our share of national resources is spent wisely and frugally. The Department of Defense is now taking the necessary steps to improve its management of research and development.

The Department of Defense must and can merit the confidence of the public and the Congress in its stewardship of all defense research and development.

Thank you, Mr. Chairman.

Mr. HECHLER. Thank you, Dr. Foster, for this extremely helpful testimony.

You commented on page 9 that the subcommittee could make a major contribution by examining the need to maintain an aeronautical research and development funding level high enough to assure our continued world leadership. We would like to assert that we have already passed that point. We recognize this need and we assert the necessity for proceeding.

The point we are at now is to determine the arguments for and the path toward maintaining this world leadership. The relationship between NACA and the development of aeronautics and development of military aviation has frequently been cited as a very fortunate relationship in the early days.

Are there any lessons that can be learned in the current relationship between our civilian aeronautical research, and military aeronautical research and the developement of aviation in general?

Dr. FOSTER. Well, Mr. Chairman, one that comes to mind immediately is the point that I have touched on in two places in this statement; and that is the necessity, each year, to ensure that the agencies of the Federal Government involved in this kind of activity renew their effort toward a coordinated operation, to achieve maximum progress with the funds available.

The reason I want to emphasize that point is simply that, while the agencies keep on coordinating the work, and while the congressional committees continue to examine the subject, the individuals in the agencies—particularly the key people—change, and they do need reminding.

Mr. HECHLER. Mr. Wydler.

Mr. WYDLER. Yes. Thank you, Dr. Foster. I am interested, there has been quite a lot of discussion, and I have received quite a bit of mail about the question of section 203 of the defense authorization bill. And I have been told that very recently the majority leader in the Senate of the United States saw fit to take issue with you on some of your interpretations of how this section is going to be used in determining what research the Defense Department will undertake.

Can you give me your interpretation of what the Congress meant when it passed section 203, as you see it, in trying to award defense-related contracts to industry?

Dr. FOSTER. Mr. Wydler, I think this is a very important matter. If I may, I would like to take a moment to discuss section 203 and the position of the Department of Defense in that regard.

At the outset, if I may, Mr. Chairman, I would like to read the directive that was signed by Deputy Secretary of Defense Packard on December 2. It was addressed to the Secretary of the Army, and the Navy and the Air Force, Director of Defense Research and En-

gineering, Assistant Secretaries of Defense, and the Directors of the Defense Agencies.

The subject of this memo is "Section 203 of Military Procurement Authorization Act." "Section 203 of the Military Procurement Authorization Act," that is Public Law 91-121, approved November 19, 1969, provides as follows:

SEC. 203. None of the funds authorized to be appropriated by this Act may be used to carry out any research project or study unless such project or study has a direct and apparent relationship to a specific military function or operation.

This provision is, in effect, reiterative of the legal principles and long-standing RDT&E policies which have governed and will continue to govern the use of defense appropriations for RDT&E activities.

Mr. HECHLER. Excuse me, Dr. Foster. In the interest of time, this letter from Secretary Packard has been printed in the Congressional Record and we have copies of it, and if it would be agreeable with you, we would just like to extend it into the record and continue.

Dr. FOSTER. Certainly, Mr. Chairman. Are you referring to the letter from the Deputy Secretary——

Mr. HECHLER. December 2.

Dr. FOSTER (continuing). To Senator Mansfield? It is included. I understand. Certainly I would be pleased to proceed that way.

Mr. HECHLER. It is printed on page S15992 of the Congressional Record of December 6, since we have copies in front of us, I think it would save time not to read it in full.

Dr. FOSTER. Thank you very much, Mr. Chairman. I would also like to include, if I may, in the record of this hearing the letter from me to Senator Mansfield on December 4. Does the committee also have copies of that?

Mr. HECHLER. I think it says here December 2, letter from Mr. Packard to Senator Mansfield, December 2. Is that the one you are referring to?

Dr. FOSTER. No, Mr. Chairman. I am referring to my letter of December 4.

Mr. HECHLER. If that is not too lengthy, perhaps you had better read that.

Dr. FOSTER. I believe it is more lengthy, Mr. Chairman, and includes the answers to a number of critical questions which the Senator addressed.

Mr. HECHLER. That will be included without objection.

(The documents follow:)

THE SECRETARY OF DEFENSE,
Washington, D.C., December 2, 1969.

Hon. MIKE MANSFIELD,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MANSFIELD: I thank you for your letter of November 20 inquiring about the Department's views regarding Section 203 of the Military Procurement Authorization Act. We appreciate your concerns and would like to explain our position.

There is absolutely no question that the Department will comply fully with the law. I have directed all components to review critically all current and proposed research and development projects and studies to ensure that they have a direct, apparent, and clearly documented relationship to one or more specifically identified military functions or operations. Any project or study which does not fulfill the criterion of Section 203 will be terminated. For your information, a copy of my memorandum on this matter is enclosed.

In addition to this comprehensive review within the Department, we have contacted the National Academy of Sciences and invited them to consider carrying out a complete examination of all projects and studies which might be regarded as marginal under the provisions of Section 203.

With respect to Dr. Foster's recent letter to Senator Fulbright concerning the impact of Section 203, I have discussed the issue in detail with Dr. Foster. He shares without reservation my firm intent to comply completely with the law.

I intend to follow this issue closely and personally in the future, and to cooperate fully with Comptroller General Staats in his review of this matter. Please be assured that in our FY 1971 budget requests and program plans, we will reflect detailed consideration of the intent of Section 203 in relation to Defense needs for research and development.

Sincerely,

DAVID PACKARD, *Deputy*.

THE SECRETARY OF DEFENSE,
Washington, D.C., December 2, 1969.

Memorandum for the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, Director of Defense Research and Engineering, Assistant Secretaries of Defense, Directors of Defense Agencies

Subject: Section 203 of Military Procurement Authorization Act.

Section 203 of the Military Procurement Authorization Act, P.L. 91–121, approved November 19, 1969, provides as follows:

"Sec. 203. None of the funds authorrized to be appropriated by this Act may be used to carry out any research project or study unless such project or study has a direct and apparent relationship to a specific military function or operation."

This provision is, in effect, reiterative of the legal principles and longstanding RDT&E policies which have governed and will continue to govern the use of Defense appropriations for RDT&E activities. However, insufficient attention has been given to making clear to the Congress the basis for deciding to support work in a particular field, and particularly the connections between relatively basic research and the long-range Defense problems and missions which require such research.

In order to assure full compliance with the intent of Congress as expressed in Section 203, addressees are requested to assure that prior to the approval of a new research project or study, or the continuation, modification or extension of an existing research project or study, the project manager furnishes a written statement which describes, as clearly and simply as possible, the project or study and its purpose, together with its direct and apparent relationship to one or more designated military functions or operations. Any project which does not have a direct and apparent relationship to a specific military function or operation must be terminated in an orderly way as soon as possible.

I have asked Dr. Foster to work with you in reviewing all current RDT&E efforts, as well as selection criteria used to evaluate proposed RDT&E studies and projects. The purpose of the review will be to assure that the long-standing Department policy, requiring that the criterion of relevance-to-military-missions be applied throughout the RDT&E program, has been and is being applied explicitly in every case. If necessary, please consider supplementing the appropriate directives to ensure that the provisions of Section 203, P.L. 91–121, are followed completely.

In summary, addressees are requested to take all necessary actions, beginning immediately, to comply fully and scrupulously with the law. Under no circumstances shall the Department support work which does not have a direct, apparent, and clearly documented relationship to one or more specifically identified military functions or operations.

DAVID PACKARD, *Deputy*.

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING,
Washington, D.C., December 4, 1969.

Hon. MIKE MANSFIELD,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MANSFIELD: Your letters to me of September 22 and November 21, along with your letter to Secretary Laird of November 20, raise many thoughtful, fundamental questions regarding the R&D needs, policies and practices of the

Defense Department. In this letter, and in the attachments to this letter, I have attempted to answer your questions.

Let me start with overall philosophy. In my view, matters of national security must be a concern of the nation's intellectual community. Our security depends critically upon first-rank science and advanced technology. More broadly, our security depends upon a deep evaluation of many economic, technical and other factors as they relate to military matters. Our understanding of these factors, each complex and related to the others, influences our perception of the military situation, and affects the difficult issues of choice and emphasis which confront us.

The Department of Defense should not rely solely on its own staff in considering its position on these matters. We must get advice and criticism of current policy from those who have a specialized grasp of each element of the problems and who at the same time have had continuing experience with putting together an integrated analysis. These specialists are drawn from the physical, engineering, and behavioral sciences as well as from interdisciplinary research areas related to national security problems. They are able to serve the Department, the Congress and the public generally because through Department of Defense sponsorship of their research they have become knowledgeable and involved in the broader implications of defense technology. You will recall, for example, that during the debate on the ABM, much of the needed expert testimony—on both sides of the main issues—was supplied by scientists and engineers who had been associated with Defense R&D carried out in universities.

The need for interaction between the Department and the research community is profoundly significant. It is not a marginal need of the Department. It is a priority need. It is not becoming less important for the nation. It is becoming more important because of the increasing complexity of military problems and equipment needs.

For the next five to ten years at least, I am greatly concerned about the trends of declining U.S. research and development while Soviet defense-related research and development increases at a disturbing rate. These trends, coupled with the still effective Soviet secrecy, mean that we cannot afford to take any greater risks in jeopardizing our position of leadership in defense technology.

This overall philosophy is the foundation of four general views we hold regarding the Department's research and development.

1. Each major department and agency should carry out a research and development program needed to meet its responsibilities, that is, needed to fulfill missions more effectively.

The purposes of research and development are to solve identified operational problems, create new or alternative ways of fulfilling missions, improve the efficiency of on-going operations, reduce costs, and broaden our framework for understanding and evaluating defense issues. The Defense Department is perhaps the leader in a commitment to this outlook. Our commitment has been based on the critical needs for technical leadership in those fields and on those systems upon which our future national security will depend. In short, the country depends upon the Department, and the Department depends upon science-based technology.

2. For a research and development effort to be healthy in the long term, it must include some investment in applied research and in relatively basic research.

Without research, all developmental efforts ultimately would be crippled because of the lack of new concepts and new data upon which to base needed technological advances. Equally important, development programs started without adequate prior research and technological [illegible]rt can become excessively costly.

Within the Defense context, basic and applied research has three major functions: to solve recognized technological problems which arise from both short- and long-range military operational requirements; to minimize the possibility of technological surprise; and, as an automatic by-product of the first two functions, to contribute to the national technical base from which all agencies of the Government, including Defense, ultimately draw their scientific ideas and skilled manpower. We choose the fields for our investment in basic research based on their potential contribution to our overall Defense R&D program, which is, in turn, directly related to the specific, approved missions of the Department.

There are a number of fields in which the Defense Department has great needs. We have unique needs, larger in number than any other mission-agency, and necessarily more focused than those of the NSF. Today these include relatively basic research in, for example, electronic engineering and physics related to

sensors and other special electronic components, oceanography, high temperature and ultra-strong materials, some areas of mathematics and computer sciences, and many areas of aerodynamics and propulsion. When other sources of support do not encourage these basic fields sufficiently, DoD must insure that the areas do not lag.

3. The Defense Department research project offices provide continuous and immediate "coupling" of research results into developmental and operational activities.

One of the general benefits of direct DoD support of research—basic and applied, unclassified and classified—is the opportunity for frequent contact and exchange with the scientists involved. This permits rapid transfer of results, and discussion of the implications of the results for Defense, including discussion of related work not supported directly by the Department. For example, the relatively basic research often leads to applied research that is classified because of its immediate relevance to military problems—and we find that some university groups wish to carry through on their basic research into this applied and prototype work needed by DoD.

The "coupling" of research results is based upon the initial choice and design of projects. We can show that needed military functions and operations will not be fulfilled without obtaining a certain technological capability, and that achieving this technological capability depends upon scientific progress not yet made in certain fields. From another perspective, we also can show the range of likely technological applications and operational missions which will be served by pursuing certain lines of basic and applied research. While the Defense project office must be able to demonstrate the military relevance of each project, the individual researcher is not so required. The researcher is frequently more interested in his research for the sake of science than for any particular application.

In summary, the management of our research programs is an active process: selecting fields relevant to Defense, and providing the feedback required to evaluate applications and modify research goals.

4. University groups represent a unique national resource of excellence in research and development. This is why we select academic investigators to carry out some of our work.

We do not develop our budgets in terms of an arbitrary funding formula to universities *per se*. Rather, we decide what research is necessary, then consider a range of possible contractors (including in-house laboratories). Overall, it turns out that universities are awarded contracts for a significant fraction—recently about 20%—of the relatively basic and applied research we need, because they are interested and best qualified. If we attempted over a period of a few years to shift very much of this work to industrial or in-house laboratories, we would obtain lower quality research and incur higher costs. This would happen because of the general excellence of university investigators in certain technical areas, and because of the lower costs in universities for comparable technical effort.

There are two additional points in your letter of September 22 that I should discuss.

You suggested that the Defense Department funds more research at universities than does the National Science Foundation. The statistics on this matter can be understood properly only with a careful review of the definitions of the categories in which the data are collected and presented. A summary of available data is given on page 4 of the attachments. My understanding of the situation is as follows.

The National Science Foundation prepares annual compilations of statistics of funding for research and educational activities. According to these compilations, in terms of the "total Federal obligations to universities" for FY 67, DoD provided 8% of the funds, NSF provided 12%, and HEW provided 68%. In terms of total Federal funding for "academic science" (i.e., excluding the support for non-science activities) in FY 68, DoD provided roughly 11% of the total Federal R&D funding to universities, compared with HEW at about 54% and NSF at about 18%.

You will note in the attached data that the standard NSF compilation is not yet available for FY 69. However, the Bureau of the Budget prepared a different kind of compilation for FY 69 which showed NSF providing $210 million, and DoD providing $247 million, to universities for the "support of research." These may be the data to which you referred in your letter of September 22. But it is

my understanding that these data are not strictly comparable because of differences in the interpretation about what kinds of research support would be reported by various agencies. For example, you will note that between FY 67–68, our support for "basic research" was less than NSF, and declined while NSF funding in this category increased. Thus the BoB data for DoD include support for considerable applied research (which is often classified) and the BoB data for NSF include support mainly for basic research.

To be specific about the funding involved recently, in FY 69 DoD provided a total of about $247 million to universities for research and development, while NSF provided about $390 million to universities for support of scientific research, the national sea-grant program, computing activities in education and research, institutional support for science, and science education support. (DoD in addition provided about $130 million in FY 69 for specialized, mainly classified R&D at university-managed groups such as the off-campus Lincoln Laboratory at MIT; but this work is not basic research, is not funded primarily from our research program, and thus is not included in the NSF compilation for "academic science.")

Clearly, on the basis of these overall data, DoD does not have a dominant position in supporting campus activities.

Finally, I would like to discuss our general position of Section 203 of the FY 1970 Military Procurement Authorization Act.

As a matter of policy, *all* proposed Defense R&D projects are required to be evaluated against five broad criteria: (1) technical quality and originality of the proposal; (2) military need or relevance of the proposed work; (3) experience and qualifications of the proposed investigators and/or program management; (4) adequacy of the facilities and other administrative arrangements needed for the proposed work; and (5) reasonableness of proposed budget. These criteria are inherent in the decision-making process on every contract award, whether it is for research or development, whether to an in-house laboratory or to a contractor, and whether on a competitive or a non-competitive basis. Obviously, we are not always satisfied with the results of our efforts, and we are conscious of the need to improve aspects of R&D management. But the test of military need, or military relevance, has been and remains absolutely fundamental to the process.

Following the enactment of Section 203, Deputy Secretary Packard directed the Military Departments and Defense Agencies to make a rigorous review of all on-going and proposed research projects to demonstrate explicitly whether and how each one is directly and coherently related to defined military functions, operations, and/or to potential military applications. This relationship must be clearly documented. Projects which do not fulfill the provisions of Section 203 will be terminated. Furthermore, we have re-emphasized the requirement to provide titles and project descriptions which will be understandable to laymen.

Implementation of Section 203 will involve complex technical interpretations and judgments. We will have to make judgments on the degree to which proposed research is directly and apparently related to specific military functions and operations. I have contacted the National Academy of Sciences and asked them to consider the possibility of assisting us in formulating criteria for our long-term use. We pledge a conscientious and open effort, at all levels of the Defense R&D community, to sort out our needs, to develop and apply unambiguous criteria in the selection of projects for Defense support, and to report our decisions in clear detail to the Congress.

Because of the special significance of Section 203 of the Military Procurement Authorization Act, I have discussed your concerns and my answer to your letter with Secretary Laird, Deputy Secretary Packard, Dr. Lee DuBridge and Dr. William McElroy. They agree with the substance of this reply. We are prepared to discuss with you any issues related to Federal support of R&D in general and of academic science in particular.

I hope very much that this letter and attachments will create the basis for constructive discussions in the future, and that an opportunity to discuss this matter with you personally can be arranged in the near future.

Sincerely,

JOHN S. FOSTER, Jr.

Attachments.

ATTACHMENT OF LETTER FROM DR. JOHN S. FOSTER, JR., TO SENATOR MIKE MANSFIELD, DECEMBER 2, 1969

ATTACHMENT: ANSWERS TO SPECIFIC QUESTIONS

1. DoD need for university research

(a) What level of university research does DoD believe necessary for the next ten years?

We do not budget for university research *per se*. We budget for research, exploratory development, advanced development, etc. We support projects at universities within these categories when it is clear the work can best be done there. This support varies from year to year depending on such factors as our overall R&D budget, our specific research needs and the number of relevant proposals received from universities. It is only after the fact in any given year that we know precisely how much support we have given to universities. Therefore, it is not possible to determine what the absolute level will be for the next ten years.

During the 1966–68 period, our support to relatively basic research progressively declined. We examined the situation before submission of the FY 69 budget and found that the overall level was at a minimum, if not too low. We found, for example, cases of rejected university proposals which were directly relevant to our needs in areas which could lead to the solution of operational deficiencies. More broadly, we found many indicators of erosion of the national base for research and technology—and, as a major national user of the knowledge and personnel produced by university and other research centers, DoD has a serious stake in their survival as effective and available sources.

The present DoD support for academic science is $247 million. This support constitutes about 11% of the total Federal funding for "academic science." We don't expect national security R&D requirements to decrease, and thus we have no reason to expect our future need for research, of the kind best carried out at universities, to be less than the present level.

(b) In what fields of science will this money be invested? Why?

As pointed out above, we cannot forecast an absolute level of funding ten years in advance. By the same token, we cannot forecast the level for each field of science.

However, we do know the current deficiencies in many military functions, which cannot be corrected without research. We have assessments of operational needs in areas such as communications; guidance, control and navigation; detection, tracking, and surveillance; materials and structures; life support; land mobility and undersea warfare; energy conversion; and missile propulsion. To meet these needs, we anticipate continuing requirements for relatively basic and applied research in many fields within the physical, engineering, environmental, and medical sciences, as well as a number of interdisciplinary research areas related to defense technology.

2. Alternative funding for such research

Why should not the NSF fund all or much of such university research of interest to DoD? Congress could, if necessary, specifically authorize NSF to do so and perhaps provide for DoD advice to NSF as to the kinds of research needed.

DoD like other mission agencies relies upon NSF to maintain an adequate base in the scientific disciplines. Above and beyond this base each mission agency must perform or sponsor additional research efforts which are specifically directed towards its identified needs and its long-term technological objectives. To achieve these objectives DoD turns in part to the university science and engineering community, and must have its own direct communication with that community. Three reasons underlie the need for this direct relationship.

(1) The need to promote and accelerate the coupling of research to applications requires close monitorship by the most concerned DoD personnel.

(2) Early feedback of research findings and conclusions, and of results of applications, is required for the timely modification of research program goals.

(3) To do the same or equivalent job NSF would have to be continually exposed to military problem areas and involved in Army, Navy, Air Force, and Defense agency briefings, program reviews, laboratory visits, evaluations, etc. Without this intimate involvement NSF would be an unnecessary and ineffective middle man without appreciation of the research relevance or of the military applications.

The following pages provide comparative data on the funding of various DoD components, as well as of other Federal agencies, for university research.

DoD R.D.T. & E. funding to universities, fiscal year 1969

	Thousands
Army:	
Army Research Office	$12,916
Army Material Command	15,411
Surgeon General	11,778
Chief of Engineers	1,166
Army Security Agency	348
Combat Developments Command	33
Safeguard	207
Advanced Ballistic Missile Defense Agency	3,854
Army total	45,713
Navy:	
Office of Naval Research	62,407
Bureau of Medicine	975
Bureau of Personnel	36
Naval Systems Commands	20,782
Navy total	84,200
Air Force:	
Office of Aerospace Research (less AFOSR)	14,500
AF Office of Scientific Research	33,200
AF Systems Command	32,300
Air Force total	80,000
ARPA	36,500
DASA	720
DoD total	247,133

FEDERAL OBLIGATIONS TO UNIVERSITIES[1]

[Dollars in millions]

	HEW	NSF	DOD	AEC	NASA	Other
I—Fiscal year 1967:						
Total obligations	2,231	395	264	110	132	180
Percent	(68)	(12)	(8)	(3)	(4)	(5)
Academic science	1,251	395	264	110	132	173
Percent	(54)	(17)	(11)	(5)	(6)	(7)
Basic research	237	197	149	82	73	46
Percent	(30)	(25)	(19)	(11)	(9)	(6)
II—Fiscal year 1968:						
Total obligations	2,248	389	230	137	114	190
Percent	(68)	(12)	(7)	(4)	(3)	(6)
Academic science	1,238	389	230	137	114	184
Percent	(54)	(17)	(10)	(6)	(5)	(8)
Basic research	258	208	128	86	58	44
Percent	(33)	(27)	(16)	(11)	(7)	(6)
III—Fiscal year 1969:						
Support of research	713	210	247	94	119	125
Percent	(47)	(14)	(16)	(6)	(8)	(9)

[1] Sources: Fiscal year 1967 and fiscal year 1968: NSF. Fiscal year 1969: BOB.

Notes: (1) Total obligations include nonscience activities largely connected with education as well as academic science which includes basic and applied research, development, R. & D. construction and facilities costs, and other science activities such as support for scholarships, fellowships and institutional development programs.

(2) NSF data in the format for fiscal year 1967–68 has not yet been published for fiscal year 1969; therefore data from BOB special analysis Q was used. Support of Research as defined therein includes research and development, i.e., it is academic science less R. & D. construction, scientific scholarships, and other institutional development programs.

WHERE DOES DOD RANK AMONG FEDERAL AGENCIES FUNDING ACADEMIC SCIENCE?

I. FEDERAL OBLIGATIONS TO UNIVERSITIES FOR "ACADEMIC SCIENCE," BY AGENCY, FOR 1967 (SOURCE NSF-69-7, p. 6)

	Millions	Percent
HEW	$1,251.0	53.9
NSF	394.5	17.0
DOD	264.1	11.3
Agriculture	144.8	6.2
NASA	131.5	5.7
AEC	109.6	4.7
Interior	23.9	1.0
Commerce	4.4	.2
Total	2,323.8	100.0

II. FEDERAL OBLIGATIONS FOR BASIC RESEARCH, BY PERFORMER AND AGENCY FOR FISCAL YEAR 1968 (EST.) (SOURCE NSF 68-27, P. 13)

	To universities and colleges—	
	Millions	Percent
HEW	$258	33
NSF	208	27
DOD	128	16
AEC	86	11
NASA	58	7
Other	44	6
Total	782	100

III. TREND IN DOD SHARE OF FEDERAL FUNDING FOR ACADEMIC RESEARCH

DOD percentage share:	
1950	80
1960	33
1970 estimate	10

While changes in categorization of academic research do not permit precise comparison, the DoD share of Federal funding to universities for research has decreased steadily during the past two decades.

3. Recent changes in DoD funding of university research

(*a*) *In what fields of university research, if any, has DoD cut back expenditures? Which, by how much?*

(*b*) *In what fields is DoD increasing its support? Which, by how much?*

Changes in the net funding to universities from the 6.1 Research budget category by the Military Departments in the various scientific fields, for FY 67, 68, and 69, are shown in the table below.

The funding data do not reveal the dollar-compensating changes (increases and reductions) which occur when modifying the relative emphasis on areas *within* each of the major categories. Such program shifts in emphasis reflect changes in degree o. relevance, newly perceived military needs, or new scientific opportunities related to existing operational problems.

6.1 RESEARCH OBLIGATIONS TO UNIVERSITIES BY THE MILITARY DEPARTMENTS

[In millions of dollars]

	Fiscal year 1967	Fiscal year 1968	Fiscal year 1969
General physics	17.4	15.0	16.4
Nuclear physics	11.3	7.9	3.8
Chemistry	6.0	5.7	6.3
Mathematics	12.4	10.5	11.6
Physical sciences (totals)	47.1	39.1	38.1
Electronics	10.0	9.2	9.4
Materials	3.6	2.7	3.5
Mechanics	8.5	6.5	6.9
Energy conversion	3.7	3.9	4.1
Engineering sciences (totals)	25.8	22.3	23.9
Terrestrial	3.3	2.6	4.2
Atmospheric	3.9	2.2	2.3
Astrophysics	3.0	2.6	2.4
Oceanography	10.2	16.0	18.2
Environmental sciences (totals)	20.4	23.4	27.1
Biological and medical	13.9	10.3	8.7
Behavioral-social	3.8	3.1	3.2
Themis [1]	19.0	26.8	29.6
Totals	130.0	125.0	130.6

[1] Themis is not broken out by disciplines because most of the programs are interdisciplinary and do not easily fit into the above categories.

(c) *What has happened to research projects dropped or cutback by DoD because of changing departmental interests?*

Research efforts which are no longer sufficiently relevant to DoD mission to justify further funding fall into one of two categories. In the first, there is sufficient relevance to the mission of some other agency or sufficient broad national interest to warrant continued Federal support, though not by DoD. In the second, there is no such interest by any other Federal agency.

In cases of the first type, after inter-agency coordination, some projects have been picked up by other agencies whose priorities and resources have also changed. NSF has taken over projects in high-energy physics and radio astronomy which dovetail with and complement their own programs in those fields. Transfers to AEC have also occurred following the appropriate inter-agency coordination and negotiation.

The process of inter-agency transfer in response to the changing needs, priorities, and resources of the various agencies has been thoroughly considered and coordinated by the agencies.

In cases of the second type, DoD simply terminates the Defense sponsorship, providing reasonable time and funds for non-disruptive phasing out by the university. A recent example of this is the Navy's termination of their 200K/year sponsorship of theoretical nuclear physics research led by a Nobel laureate.

4. *DoD access to information about university research*

(a) *What access does DoD have to project information systems of other agencies that fund university research?*

DoD has full access to all technical information, as well as general management information, regarding the R&D programs of all Federal agencies.

Because of the continuing formal and informal communications within the technical community, DoD's project managers know in advance about the fields in which major awards are to be made. In addition, DoD's project offices participate in a wide range of technical coordination activities designed to review the results of all agencies' work, even though most of each mission agency's basic and applied research is not directly relevant to the other agencies.

To illustrate the kind of coordination, there are special or ad hoc committees on high-energy physics and radio astronomy (DoD–NSF and DoD–AEC), on interdisciplinary research at universities (DoD–NASA); and special seminars on research program management (DoD–NIH). In addition, there are computer-

assisted information systems in various agencies which are used to provide working-level scientists with brief resumes of on-going projects.

(*b*) *Conversely, what access to DoD project information systems do these agencies have?*

Exchanges such as those mentioned above provide full access by other agencies to DoD's programs.

Every agency has direct access through the Defense Documentation Center's 1498 technical project summary system. This is an information bank containing a description of all research projects under DoD sponsorship, university, industry, and in-house. In addition, monthly lists of new proposals received and/or acted upon by DoD agencies are provided to other agencies.

(*c*) *Within the Defense Department, what measures are there for assuring that administrators who decide what university research to support and which university research proposals to select are informed of related research projects funded by other DoD agencies?*

The scientists in each DoD research office are in close contact with their counterparts, field by field, in other offices. One of the most important formal techniques for pre-award consultation is the monthly exchange of listings of all proposals received during the month. These same listings announce proposals previously listed that have been acted upon in term of rejection, acceptance, or further evaluation. Such listings are exchanged among all major R&D-sponsoring agencies within DoD.

5. Origins of DoD university research projects

How many DoD funded university research projects result from formal requests for proposals? How man from unsolicited proposals? (Latest available fiscal year information for each DoD agency that funds university research)

The programs of the Services and the DoD agencies are derived from responses to Defense-expressed areas of need and interest. Thus even seemingly unsolicited proposals are in a very real sense responsive to an expressed need. As a matter of long-standing practice throughout the Federal government, there are very few formal requests in the legal sense for proposals from universities; this is also the case for DoD.

DoD research offices and laboratories publicize the areas of military research needs by means of bulletins and brochures; and personally communicate our areas of prime interest at conferences, symposia and professional meetings attended by scientists in all significant fields. Furthermore we accept only proposals which are addressed to areas relevant to our needs.

In the case of the THEMIS program, for 3 successive years proposals were formally solicited by letters to all universities awarding doctorates in science and engineering. The letter was accompanied by a formal brochure setting forth areas of interest, eligibility rules, criteria for selection, mode of funding, etc. Approximately one thousand proposals were received and evaluated, and from these 118 awards were made.

Depending on the year, the ratio of proposals-received to awards-made (to universities) is 6/1 to 10/1.

6. Implications of project hindsight

(*a*) *These two findings (Sherwin and Isenson on HINDSIGHT in Science 23 June 1967, versus Price and Bass, Science 16 May 1969, on research inputs to weapons development) seem at variance. Which view prevails?*

There is no basic conflict between the Price/Bass report and the Project Hindsight report.

In the Hindsight study, 20 military systems were investigated and analyzed by technical specialists to determine the innovations in each system which contributed to the system's enhanced capabilities as compared to its predecessor systems. These innovations were then traced back to their origin in applied science or technology. Even though some of the innovations traced back to 1945, Hindsight's methodology was designed to look at relatively recent science and technology as it was utilized in weapon systems. The methodology was not designed to identify the fundamental origins of the related basic science.

The Price/Bass article looked at the origins of basic research findings, rather than the system applications, and showed how fundamental scientific findings feed the innovative process. The key point of the Price/Bass article was that the innovative process is possible primarily because basic research supplies the base of knowledge on which technological innovation depends.

In summary, the two studies were complimentary in that they look at the innovative process from opposite aspects.

We do not believe that either study provides a "correct general formula" for R&D management.

(b) Why should not the desired undirected research be [illegible]ined in large measure from the department's own laboratories, thus decreasing the involvement of university researchers with Defense interests?

The Defense Department does not support "undirected research." Further, the Department should not decrease its involvement with the university research community.

As explained in detail in the accompanying letter, the Department needs certain specific research which often can be carried out best by university groups. More broadly, the country benefits from broad contacts by the research community with national security issues. If the Department tried to shift very much of the current DoD-sponsored university effort to industrial or in-house laboratories, we would obtain lower quality research at higher cost.

Moreover, it is definitely in the national interest to maintain in the interaction between the military establishment and that knowledgeable sector of society which through experience with Defense research problems is capable of meaningful and independent criticism of and suggestions for Defense concepts, policies, and technological decisions.

Dr. FOSTER. Now I would like to try and answer your question, Mr. Wydler.

Prior to the enactment of section 203, the Department of Defense anticipated cuts by the Congress of at least 10 percent in the area of basic and exploratory research and development.

As a consequence, realizing that we would not receive the fiscal 1970 moneys until we were roughly halfway through the year, we had to take action shortly after the start of the fiscal year to reduce our expenditures. This was necessary because, although we are permitted to proceed at the finding level of the prior year, fiscal 1969, we would reach an extremely difficult financial position in the latter half of fiscal 1970.

Accordingly, I reviewed with the Assistant Secretaries of the military departments and the directors of defense agencies the criteria by which we should make the necessary reduction in advance of the congressional action.

As you know, the criteria that are usually applied involve the necessity for excellence, the capabilities of the performers, the facilities that are involved, the reasonableness of the costs, and so on. But, in particular, we have required that the work be relevant to the mission of the Department of Defense.

And so, in establishing the criteria, we determined that the first efforts to be reduced or deleted should be those that are least relevant to our mission.

Now this effort involved an examination of 10,000 to 12,000 different work units. You see, the act refers to every activity in the Department of Defense, activities in industry, and activities in the Government's research and development laboratories.

The review of these thousands of work units is still in progress. My feeling, however, is that the cuts already imposed by the Congress will involve reduction of effort and termination of contracts far in excess of any projects that will be identified as having marginal relationship to military functions or operations.

Thus, we have already made reductions—and will in the near future be making further reductions—through the sheer limitation of funding; and other agencies will have an opportunity to look at these reduc-

tions and terminations and determine whether or not, in the interests of their missions and within their funding abilities, they are in a position to absorb these programs or augment them.

The specific question of the determination of relevance is a very difficult one, Mr. Wydler. It involves individual judgments, military and technical.

Mr. WYDLER. I don't think that is relevant, if you will excuse me. The language of section 203 does not discuss relevance at all. It discusses direct and apparent relationships, and I think that if you are going to try to follow the language of the act, and the limitations on you, you have to get away from a term such as "relevance," which doesn't sound to me to have any relevance to what you are trying to do.

You are using a term which probably, I can understand, would suit your purposes better than the language of the act, but I am just saying that in reading the act it talks about direct and apparent relationship, and it seems to me that is the language you have to deal with, now in the Department of Defense.

Dr. FOSTER. Quite so, Mr. Wydler, and we shall. For the word "relationship," I used "relevance," but I quite understand that we should use "relationship."

The matter of determining whether or not there is a direct and apparent relationship is a matter of judgment concerning technical aspects of the research and the mission and operations of the Department of Defense.

And, so in each one of these researches, one has to look at the nature of the work and determine the relationship of that research effort to military missions and operations.

Mr. HECHLER. Would it be OK with you if we narrow your inquiry as it relates to aeronautics and aviation?

Mr. WYDLER. I would just like an example of what isn't relevant or isn't a direct and apparent relationship, in your opinion, to defense matters. Because I can see where you could easily interpret that to mean anything in the world. I can see where anything in the world has some relation to defense, so I can't think of anything you couldn't interpret as being relevant.

That is why I don't like that word particularly, and "direct" and "apparent" seems to be much stronger or much more defining or confining word. That is why I think that they were put in in that way.

And I presume they were meant to mean something different, direct, and apparent. Meaning that the average person would think of them as being direct and apparent. Obvious things, I suppose, is another word for it.

Could you give me an illustration of something you think wouldn't be a direct and apparent relationship to defense?

Dr. FOSTER. Yes, I believe I could. If a researcher wished to study the basic theoretical considerations of, let us say, nuclear structure, and knowledgeable individuals had no reason to believe that these considerations had any bearing on the problems of the military, then I don't believe, under the interpretation of this law, there would be any justification for our funding the activity.

Mr. WYDLER. That really is a strange selection you have made, because I can't consider anything that has proven more significant militarily than probably the research on the atom that Professor Einstein did, although I am sure he didn't have any idea he was doing anything that was going to have a military significance when he did it.

And as it turned out, of course, it is probably the most significant military thing that has been done in our generation, isn't that the way it turned out?

Dr. FOSTER. It certainly did, Mr. Wydler. However, as I understand the act, one would have to have some foresight in order to be able to make that relationship direct and apparent.

And if one has that foresight, either a technical man or a layman, then I believe you could accept it. If you don't have it, then it will not be accepted. So in my judgment we will take those items that are marginal and bring them to the attention of the key people in the Department of Defense, we will discuss them with the GAO, and, if in our judgment they are marginal, they will have to be canceled because there is not enough money to carry even those that do have a direct and apparent relationship to military uses.

Mr. WYDLER. To follow up on the chairman's suggestion, could you give me an illustration possibly in the field of aeronautics that wouldn't have a military relevance?

Dr. FOSTER. Certainly. One that would not?

Mr. WYDLER. Not.

Mr. HECHLER. Before you proceed, I have a list of a number of——

Mr. WYDLER. I can't think of any myself.

Mr. HECHLER. I have a list of projects and programs on aeronautics, including a $624,000 program on V/STOL aerodynamics, which happens to be at West Virginia University.

Dr. FOSTER. Yes, sir.

Mr. WYDLER. That is the one.

Mr. HECHLER. For the benefit of another distinguished member of the full committee—I see another one here—at Texas A. & M. aircraft dynamics in subsonic flight.

The first one was a Navy contract. The second is an Army contract.

I don't know whether you have enough information on these contracts or their internal nature to give a snap decision.

Dr. FOSTER. I doubt that I do, Mr. Chairman. However, if you would give me the questions I would be glad to submit my judgment for the record.

(Information for the record follows:)

The solicitation for Project THEMIS proposals defined eight research problem areas of particular interest to DoD. The current THEMIS aeronautics programs listed in the following table were reviewed, and a determination was made that each has a direct relationship to military functions. A brief description is given of the two specifically mentioned.

PROJECT THEMIS PROGRAMS ON AERONAUTICS

Military department	College or university	Program subject	Funding through 1969
Air Force	University of California, San Diego, Calif.	Transport Phenomena in Flow Systems	$823,000
Do	Illinois Institute of Technology, Chicago, Ill.	V/STOL Aerodynamics	614,000
Navy	University of Minnesota, Minneapolis, Minn.	Gas Turbine Technology	800,000
Army	Mississippi State University, State College, Miss.	Rotor and Propeller Aerodynamics	557,000
Air Force	Rutgers University, New Brunswick, N.J.	Fluid Flow Aerodynamics	600,000
Army	University of Cincinnati, Cincinnati, Ohio	Internal Aerodynamics in Air-Breathing Engines	600,000
Do	Texas A. & M., College Station, Tex.	Aircraft Dynamics in Subsonic Flight	582,000
Air Force	University of Utah, Salt Lake City, Utah	Chemistry of Combustion	798,000
Navy	West Virginia University, Morgantown, W. Va.	V/STOL Aerodynamics	624,000

THEMIS

West Virginia: Navy V/STOL Aerodynamics

Objective: To develop a body of knowledge in V/STOL aircraft aerodynamics for Navy operating conditions and environments. This interdisciplinary program seeks to achieve higher lift capabilities, improved control and response, and increased cruise speeds for STOL and VTOL aircraft operational characteristics. This effort will contribute to military operations such as air search and rescue, Air ASW, amphibious air support, and fleet support.

Texas A&M: Aircraft Dynamics for Subsonic Flight (Army)

Objective: To obtain a better understanding of aerodynamic and aeroelastic phenomena relating to the performance, stability, and behavior of fixed wing and rotary wing aircraft in subsonic flight. Studies will be conducted in: aircraft response to atmospheric disturbances; unsteady separated vortex flows and wing-vortex interaction; rotary wing aerodynamics including compressibility and high frequency effects; and rotary blade-tip vortices and blade vortex interactions. This effort will contribute to military operations such as air mobility, close air support, artillery spotting, medical evacuation and battlefield surveillance.

Mr. HECHLER. Yes, that might be helpful.

Mr. WYDLER. I am not trying to put you on the spot. I can see the difficulty in trying to apply this language to an actual case. I mean, it is easy enough to write it down as it is written down, but to ask you to try to apply it to specific cases, it becomes very difficult, and as far as I am concerned, I would just as soon, unless you want to add some illustration of some aeronautical research project that couldn't possibly have any relation to the military, I will go on with something else.

Mr. HECHLER. Did you want to add anything?

Dr. FOSTER. No, Mr. Chairman. I imagine if one thought about it, one might be able to come up with aspects of commercial aviation involving aerodynamic considerations that are peculiar to the commercial aspects and not to the military, although at the moment I can't think of one.

Aeronautics research is unique in that identification of any portion of aeronautics research that does not relate to military aviation is a difficult problem. While all military aeronautical research will not have civilian application, the military has some interest in all civilian aeronautics research developments. This is because the military does transport passengers and cargo in a fashion similar to the civilian sector. Aeronautics is a unique research area. However, the following projects have been identified in the initial stages of our evaluation as being marginal in satisfying Section 203. They were selected from a large number of Air Force projects which the GAO reviewed for direct and apparent relationship to the DOD. From this review, the GAO selected 46 that they believed were questionable. After a further DOD review and evaluation against Section 203 of the FY 1970 Military Authorization Act, it was agreed that these projects were marginal in this respect.

TITLE

1. Methodology for analysis of internal social movements.
2. Criteria for the design of new forms of organization.
3. Socio-cultural aspects of development.
4. Theoretical investigations in quantum field theory and elementary particle physics.
5. Cosmic radiation of extremely high energy.

Mr. WYDLER. I imagine you could think of something such as passenger loading problems, that even those might possibly even have a relationship to defense in many ways, so it is very difficult, I can understand.

What I wanted to ask you was something, for instance, about the problem we are suffering in aeronautics in the Defense Department now in, for instance, the C–5A. And I am not getting into the question of how much it costs or whether it costs too much. We have had that done and are still doing it in three or four other committees.

I am more interested in it from this point of view. Whatever the C–5A ends up costing the Federal Government, from the defense budget, I presume at some point in time the C–5A will be adapted and become known as the C-something or other and become a commercial aircraft.

Is there any way that the Government gets any return for the cost of the development of this aircraft, when one or more companies start to sell the aircraft for commercial use and realize a profit on it?

Dr. FOSTER. Yes, there is, Mr. Wydler. When an aircraft is developed for the Department of Defense, the Department of Defense—the Government, of course—pays the development costs, including tooling and fixtures and so on.

Should the company, however, choose to reconfigure the aircraft for commercial use and start producing it, the advantages to the civil sector of the DOD's prior development effort would be apparent.

However, the company, which is gaining an advantage, not only for the civilian sector but also, competitively for itself, is asked to repay the Government for those facilities and features that it uses for the civil aircraft that were derived directly by Government funding. That is one example.

Mr. WYDLER. Well, that would be, for example, would you mean the aircraft itself, of course, is a result of the Government funding and effort, isn't it? Totally. It wouldn't be such an aircraft unless the Department of Defense had funded its whole development from top to bottom.

Dr. FOSTER. That is right.

Mr. WYDLER. Of course there could be some parts of it that already existed. I can understand that, and some equipment that had previously been developed, but the aircraft frame and motors and body and so forth itself is all a result of the Government effort, isn't it?

Dr. FOSTER. That is right, and in the case of the Boeing 707, which was derived in the early stages rather directly from the Air Force's C–135 or KC–135 aircraft, the Government negotiators worked with Boeing Airplane Co. to assure that there was an equity in the company's use of the facilities and the equipment that had been provided by the Government.

Mr. WYDLER. Are you talking about the facilities and the use of them at the time they were building civilian aircraft or are you talking about them prior to that time?

Dr. FOSTER. Prior to that time, yes.

Mr. WYDLER. Would you give us for the record the figures that the Government recouped of its total development cost for the—what did you call it?

Dr. FOSTER. C–135.

Mr. WYDLER. C–135, as a result of these negotiations?

Dr. FOSTER. Yes, I would be pleased to.

Mr. WYDLER. The amount it cost the Government and the amount that we recovered and the basis on which that figure was derived.

Dr. FOSTER. Yes.

(Information for the record follows:)

The basis for recoupment was negotiated, based on an allocation of common tooling against a predicted commercial production run of 200 aircraft. The KC-135 tooling cost was $85,555,012, of which $16,650,442 worth was common to the Boeing 707. The total recouped as rental fees was $19,457,209.

Mr. WYDLER. And this same situation will exist regarding any civilian development of the C-5A?

Dr. FOSTER. I don't know that it will fund a civilian use, sir.

Mr. WYLDER. Assuming that there is any use made of it.

Dr. FOSTER. That is right, sir. The C-5A development program included the provision that the testing would be compatible with the requirements of the FAA for the civil application of that aircraft. So that aspect of it is already being considered.

Mr. WYDLER. You mean we have already collected something on that?

Dr. FOSTER. No, but we have already looked into the possibility that such an aircraft might be useful to the civilian sector.

Mr. WYDLER. Oh, I am well aware of that.

Dr. FOSTER. So we have considered that part. But until one seriously looks at the application, I don't know what kind of arrangements would be made.

Mr. WYDLER. Well, isn't that a part of the contract that you have with the company at this point, as to what their future liabilities in this connection are going to be?

Dr. FOSTER. I don't know the details on that, Mr. Wydler.

Mr. WYDLER. Again, would you supply that for the record?

Dr. FOSTER. Yes, sir, I shall.

(Information for the record is as follows:)

In regard to the question of the government's recouping some of its investment in research, development, tooling, etc. in the event that a commercial version of the C-5A is marketed, the C-5A contract reads as follows:

"PART XIX—COMMERCIAL SALES

"In the event the Contractor enters into commercial sales, which shall be deemed to be sales other than to or through the United States Government, as a result of the development of the items called for herein, the Contractor shall negotiate with the Government an equitable (i) reduction from the final contract price or (ii) payment to the Government for the proration of non-recurring program costs, learning benefits from military production, and research and development costs applicable to this contract. The Contractor shall negotiate with the Government for use of Government-owned special tooling, and pursuant to the provisions of the applicable facilities contracts, the use of Government-owned facilities, machinery, and equipment. The Government is under no obligation to permit the Contractor to use such special tooling, facilities, machinery, and equipment for commercial production."

Mr. WYDLER. I guess I can't do this. You won't let me go out into the space program. I was just interested in the relationship that now exists between NASA and DOD, but I guess I can wait for Dr. Seamans to testify.

That is all, Mr. Chairman.

Mr. HECHLER. Mr. Lukens.

Mr. LUKENS. Thank you, Mr. Chairman.

Mr. WYDLER. Oh, excuse me, if I might. I have one further question. Will you yield to me?

On page 6 of your statement you say to me that substantially more efficient and timely use of available resources could be made if NASA worked to coordinate overall research programs more closely in the interests of all users. What are you suggesting there?

Dr. FOSTER. In my discussions with Dr. Paine, we agreed that NASA could and should make a larger effort in this area. In recent years NASA has almost doubled its effort in the aeronautics field each year. This additional effort will take more people, and that's the kind of effort that I am suggesting, as I believe it will be helpful.

Mr. WYDLER. Yes, but here you are saying that the coordination could be done better, more closely in the interests of all users. Now, what suggestion could you make to do it better?

Dr. FOSTER. Well, for example, I think it would be a great advantage to this country if NASA would build up the effort to the point where they served as the data bank for the whole area of aeronautics, as the NACA did were before the space era began.

Now that requires just a constant increase of effort over the next few years—effort in the research facilities and effort in tying in the industrial contractors and all their facilities as well as the other agencies.

Mr. WYDLER. But what is the coordination that you want to improve?

Dr. FOSTER. You see, at this moment the many individual aircraft companies around the country do much of their own development work. They do it because in recent years NASA, with the tremendous load of the space program, has had to draw people from its laboratories in the aeronautics field into the space program. As a consequence, with the continuing demand for aeronautical research by the Departments of Defense, Transportation, and others, the individual companies have had to put up their own facilities and develop their own data banks. These data banks are not integrated on a national scale.

Mr. WYDLER. Well, I understand that. You are not talking about coordination between NASA and DOD.

Dr. FOSTER. No, sir.

Mr. WYDLER. You are talking about NASA and distant companies. Thank you, Mr. Chairman.

Mr. HECHLER. And perhaps one of the solutions would be contained in what you give a clue to in the second sentence of your statement on page 6; solution to this problem lies in coordination and leadership within the executive.

Dr. FOSTER. Yes, sir.

Mr. HECHLER. And one of the purposes of this hearing, I think, is to focus a little more attention on the need for raising the entire status of aeronautics in the national policy picture.

Dr. FOSTER. That is certainly so, Mr. Chairman.

Mr. HECHLER. Is there anything further you'd like to add to that point?

Dr. FOSTER. Well, I have tried to assure the committee, Mr. Chairman, that the Department of Defense will do everything that it can to assist this committee in that regard.

Mr. HECHLER. Yes. Mr. Lukens.

Mr. LUKENS. Yes, Dr. Foster, let me first of all say that I am proud for many reasons, but I am proud of belonging to an administration and philosophy currently evident in the Department of Defense that

has seen fit to cut beyond congressional requests, for the first time in this decade, many programs, some of which have been duplicated or overduplicated, and others which have been simply overextended and others which are perhaps not as necessary as they thought. But at least we belong to an age now in the last 10 years to see the first cut psychology manifest itself in DOD, and I think you should be commended for your part in this.

Second, I would like to say it is very easy to forget that this country is—I hate to make a speech, Mr. Chairman, taking the liberty of the committee here—this country is free because we are strong, and we are strong because DOD and defense-related agencies have done this work and done the job, and for this I am extremely grateful, personally and as a public servant.

Third, it is very easy to criticize DOD because by size alone, by sheer view of the definition of size, you are going to step on more toes than I think any other agency in this Government. And I hope you understand the questions we offer are really not in a critical vein, but are more in an analytical vein, but may take the outward appearance of criticism. The point is this: Like the Post Office Department, the Government cannot reasonably expect to return money or profit on its investments. DOD's greatest service to this country is the freedom we enjoy, and this I want to commend you on, and I stand behind the agency a hundred percent. I think you would operate a lot more effectively if politics could be removed, but this is not the scheme in America, so therefore we just bear this unnecessary—or, if you like, bear this necessary weight. And I think you bear it very well, fortunately.

I am interested only in the efficiency of the DOD. I think we are all interested in that, and I think that you have been very efficient as a body, because I have seen Government do much worse than DOD. Right here in the Congress, I think we have examples where we certainly shouldn't be throwing too many stones, because we do live in an extremely glassified house, if you will.

Now, I want to know basically if the spin-off technology, things we learn peripherally or tangentially, how you do make a determination, what your management approach to saying this is relevant, or if you like, related, or is this necessary. Is there a need for example, work with dolphins for underwater transmission of signals. I understand we have learned a great deal from a project that on the surface would seem to offer no apparent relationship, explicit or general, to military, and yet indeed has a great deal to do with underwater sonar.

Dr. Foster. Well, it is certainly true. And as I said before, the difficulty we have had is in this matter of judgment. To a layman, the fact that the Department of Defense was studying the cold adaptation of Korean women divers was a subject of much amusement. But to the naval flier who is down in the waters of the North Sea, it is a matter of minutes before he may be too numb to fight for his life.

We have lost so many men that way that when we found the Korean women pearl divers can expose themselves to 5 or 8 hours a day in the coldest waters that people endure voluntarily, day after day, it seemed important that we try to understand whether it was something in the diet or something else special that enabled these people to live that way.

And so today I would say that has a direct and apparent relationship to a military operation.

Mr. LUKENS. I want to ask specifically about this interesting comment, and your reply to Mr. Fulbright and the other body, and with whom I must say I take great exception to his unjustified criticism of the Defense Department in many areas. Not in all, but in many. I might say most. You state here that pigeons have been used most recently to cull defective items from pharmaceutical and electric signal component inspection lines. Bring that down to layman's language. What do pigeons do? Besides the obvious.

Dr. FOSTER. Pigeons can be trained to peck at a particular characteristic when a production line of things is flowing along on a belt; it is very, very difficult for people looking at a sea of aspirin tablets, for example, to notice differences.

Mr. LUKENS. They can particularly cull out a defective item?

Dr. FOSTER. Exactly. There is something special about birds that has to do with visual acuity. Now from the point of view of the Department of Defense, the fact that they fly and have this visual acuity is important. Let me give you an example, because I happen to believe that in this case also there is a direct and apparent relationship to military operations.

In Vietnam, as you know, there is tall grass, called elephant grass, and as you walk through it you can't see very far ahead of you. However, if you are in a helicopter overhead, it is very obvious where everything is, because you are looking straight down along through the grass, and you can easily see the combatants, even though they can't see each other 10 or 20 feet away. And so it is possible, for example, that a bird could be used to go from its master, up into the air, and take some action, as a result of training, to indicate whether or not anyone else was around. Now, it turns out that crows are particularly useful, when they are trained this way. So again I would say that there is a direct relationship to the military operation.

Mr. LUKENS. If I might be permitted to coin a phrase, "air dog," because you already have a seeing-eye dog.

Mr. HECHLER. The Chair I think is going to have to invoke section 203 to restrict these hearings to a direct and apparent relation to the questions and the purpose of the hearing, and I would add the Secretary of the Air Force has been waiting nearly an hour, and——

Mr. LUKENS. I think the Secretary of the Air Force would be happy to wait in a situation where it acrues so much benefit.

Mr. HECHLER. Thank you, Mr. Lukens.

Mr. Goldwater.

Mr. GOLDWATER. Thank you, Mr. Chairman.

Dr. Foster, I certainly enjoyed your remarks today and I just wanted to perhaps suggest that you supply for the record, in the case brought out by Mr. Wydler, the amounts of money that have been returned to the Government from development of the 707 by Boeing.

Dr. FOSTER. Yes, sir.

Mr. GOLDWATER. I think it would be interesting to see that.

Dr. FOSTER. I certainly will.

Mr. GOLDWATER. And second of all, I wonder if you could clarify what you mean by the technology base—and also, it is in that regard, it seems to me in your statement—I think on page 5—that we have

consumed our technology base because of the war. It seems to me just on the contrary, that in the times of great demand, brought on by war, that we would be expanding this area, not consuming it.

Dr. FOSTER. That's a rather critical and important question, sir. First of all, by technology base I mean the studies of materials—materials that do not fatigue so easily, that have greater strength properties, do not corrode, things of that nature. It might also include the understanding of air dynamics—the details of why wind-tunnel and actual flight characteristics differ.

All of these things add up to our being able to build a better airplane.

In the last several years, however, because of the urgent needs of Southeast Asia, we have swept up these things that were available to help us solve our difficult problems. But it wasn't only that we swept up things—we swept up the people that knew them best; so the people who did the exploratory and advanced development were the ones who were able to take those items and put them into advanced development, engineering development, and final production.

And so in the interim, in these several years, results of relatively basic and exploratory efforts have been depleted, and so we now must fill up that void. Either the people who helped us put these things into production must go back or we must replace them with others who can work in that new area and again build up the base.

Mr. GOLDWATER. This seems to me that, as I can recall back a few years ago, and perhaps I am closer to it than some, before I got into Congress I had a little business where I supplied technical employees to the aerospace industry, and we had a tremendous time finding qualified people when there was a big push on, not only because of space but because of the war effort. And now today, a lot of these people are running around looking for jobs. These are well qualified people. And so it seems to me that during that period of time when there was a big push on, during the big push for the war and space that, we weren't really consuming, it seemed to me like we were expanding. But I'll take what you say.

Dr. FOSTER. I think, Mr. Goldwater, the point is that we were expanding there more in the end military applications than in the technology base. And it is true there are a lot of very able people around, and the reason that they are not to replenish our technology case is in part because we are limited in funds.

Mr. GOLDWATER. I see. Thank you.

I have no further questions, Mr. Chairman.

Mr. HECHLER. Thank you, Dr. Foster.

Mr. WYDLER. Could I make one observation? You know, in a way I can't help thinking of section 203 as a pat on the back for the Department of Defense, because it indicates that you weren't really spending all your money just on military weapons but you were concerned and bothered with the civilian problems of the country as well. At least that is the implication I read into it. You were spending your money foolishly by doing research on nonweapons or nonmilitary items. I don't know if that is a criticism or not, but a lot of people, particularly some of your severest critics, should consider that a compliment.

That is all, Mr. Chairman.

Dr. FOSTER. Mr. Wydler, I think there was work going on that some people felt had very, very little direct relationship to our operations or activities. With respect to the universities however, I believe—and I think others do also—that is of paramount importance that the matters of national security be intimately connected with our intellectual centers, the academic community, and that in past years the Department of Defense, recognizing this basic need as well as our detailed technical needs, has gone to the universities for assistance.

Mr. HECHLER. Thank you very much, Dr. Foster, for all this excellent testimony. If there are no further questions, we will proceed with Hon. Robert C. Seamans, Jr., Secretary of the Air Force, one of NASA's most distinguished alumni, the former Deputy Administrator of NASA.

Mr. Secretary, would you care to summarize your statement, or proceed just in any way that you care to? We are going on until the second bell, then we will have a 10- or 15-minute recess while the members answer the quorum. But you may proceed in any manner which you care to, for the benefit of the committee.

STATEMENT OF HON. ROBERT C. SEAMANS, JR., SECRETARY OF THE U.S. AIR FORCE

BIOGRAPHY OF DR. ROBERT CHANNING SEAMANS, JR., SECRETARY OF THE AIR FORCE

Dr. Robert C. Seamans, Jr., became Secretary of the Air Force on February 15, 1969. Prior to his appointment as Secretary, he was the Jerome Clarke Hunsaker Professor, a Massachusetts Institute of Technology (M.I.T.) endowed visiting professorship in the Department of Aeronautics and Astronautics in honor of the founder of the Aeronautical Engineering Department at M.I.T. He also was a consultant to the Administrator of the National Aeronautics and Space Administration (NASA).

Dr. Seamans has been active in the fields of missiles and aeronautics since 1941. From 1941 to 1955 he held teaching and project-management positions at M.I.T. In 1960 he joined NASA as Associate Administrator and then became Deputy Administrator.

From 1948 to 1958, he served on technical committees of NASA's predecessor organization, the National Advisory Committee for Aeronautics. He served as a consultant to the Scientific Advisory Board of the Air Force from 1957 to 1959, as a member of the board from 1959 to 1962, and as an associate advisor from 1962 to 1967. He is a National Delegate, Advisory Group for Aerospace Research and Development (NATO), and a member of the International Academy of Astronautics.

Dr. Seamans was born on October 30, 1918, in Salem, Mass. He attended the Lenox School, Lenox, Mass.; earned a bachelor of science degree in engineering at Harvard University in 1939; and at M.I.T. a master of science degree in aeronautics in 1942, and a doctor of science degree in instrumentation in 1951. He has received honorary doctor of science degrees from Rollins College and New York University. He is a member of the Board of Overseers at Harvard University.

He held teaching and project-management positions at M.I.T. from 1941 to 1955. These included: Assistant Professor and then Associate Professor, Department of Aeronautical Engineering; Project Engineer, Instrumentation Laboratory; Chief Engineer of Project Meteor; Director of the Flight Control Laboratory.

He joined the Radio Corporation of America in 1955 as Management of the Airborne Systems Laboratory and Chief Systems Engineer of the Airborne Systems Department. In 1958 he became Chief Engineer of the Missile Electronics and Controls Division at RCA in Burlington, Mass.

In 1960 Dr. Seamans joined NASA as Associate Administrator with responsibilities for research and development programs, field laboratories, assembling and launching facilities, and a worldwide network of tracking stations. From

December 1965 until January 1968 he was Deputy Administrator of NASA retaining many of the management responsibilities of his prior position.

He was appointed a visiting professor at M.I.T. in March 1968 and became the Jerome Clarke Hunsaker Professor in July 1968.

Dr. Seamans is a member of Sigma Xi; the American Association for the Advancement of Science; American Astronautical Society; American Society for Public Administration; American Academy of Arts and Sciences (Boston); National Space Club; Foreign Policy Association; and National Academy of Engineering.

He has received the following awards: Naval Ordnance Development Award (1945); American Institute of Aeronautics and Astronautics, Sperry Award (1951); Godfrey L. Cabot Aviation Award (1965); NASA Distinguished Service Medal (1965); Goddard Trophy (1968); NASA Distinguished Service Medal (1969).

Dr. Seamans is married to the former Eugenia A. Merrill, and they have five children: Mrs. Katharine Padulo; Robert C. III; Joseph; May; and Daniel.

PREPARED STATEMENT OF HONORABLE ROBERT C. SEAMANS, JR., SECRETARY OF THE AIR FORCE

Mr. Chairman and Members of the Subcommittee, the subject of Aeronautical research is of primary importance to the Air Force. We have good aircraft, but many of them are now getting old and may soon be obsolete.

Our best air-to-air fighter, the F-4, first flew in 1958. It is still in a class with the Mig-21, but the Soviets displayed six new fighters at the Domodedovo Air Show of July 1967, raising serious questions about our relative capability in coming years.

In the area of strategic bombers, our B-52 first flew in 1952 and the last aircraft was produced in 1962. In the meantime, aeronautical technology has advanced a considerable distance, and Soviet air defenses have greatly improved.

If we are to maintain an adequate air force, we must continually press forward with our aeronautical research and aircraft development programs. In this process, cooperation between NASA and the Air Force is a critical factor.

The F-15 air-to-air fighter

To counter a growing Soviet threat to our air superiority capability the Air Force is developing the F-15 fighter. The F-15 concept calls for a fixed wing, two engine, single seat fighter having superior performance over a broad range of altitudes and speeds. It will also have high thrust to weight and low wing loading to satisfy its high performance requirements.

NASA has been assisting the Air Force in this effort ever since the conceptional team was formed to conduct in-house analysis and wind tunnel tests. NASA technical personnel participated with our contractors in additional wind tunnel test and analysis and in turn worked with the Air Force in evaluating the contractor's studies. NASA again made important contributions in preparation of the Request for Proposal which was used in the Definition Phase of the F-15. During this phase NASA engineers were members of the Evaluation Team which conducted program reviews of the contractors' approaches to designing and managing the F-15 development. During the last several months engineers from NASA have been acting as technical advisors to the Source Selection Board in evaluating and analyzing the work of the three contractors so that source selection can be made and the winner announced by the first of the year.

All of the F-15 contractors have indicated a desire to use NASA facilities and expertise in the development of this new aircraft. NASA facilities are particularly suitable for inlet and aft body tests, pressure distribution studies and tests of stability and control.

NASA direct support of contractors is critically important to the success of our development efforts. We must determine how well configurations work over wide speed and altitude ranges. Contractors have some wind tunnels and have access to the Cornell Aeronautical Laboratory and Air Force laboratories, but much of their work must be done at NASA labs. This should be considered essential R&D assistance and should be funded accordingly.

The B-1 strategic bomber

The U.S. has maintained both a missile force and a bomber force to ensure against unexpected Soviet developments affecting either one of these systems. In view of our aging B-52s we need to move forward with the engineering develop-

ment of an advanced bomber. Even if we do so, we cannot have an improved strategic aircraft ready until 1976 or later.

To date we have been working on advanced developments and system studies which will permit a reduction in development lead time and the associated technical risk. Our advanced development efforts have included work in propulsion and avionics, with the preliminary design studies providing characteristics, configuration, and initial design data. We must solve such problems as whether the B-1 should have variable sweep wings and how we can best provide for high subsonic speed at low altitudes.

NASA support of the B-1 program will be needed in many areas. We hope to use the expertise of 6 to 10 NASA personnel as part of the source selection teams. Subsequent to source selection, continuous liaison will be maintained with NASA so that their expertise can be used should any problems develop in internal or external aerodynamics, aircraft handling, stability, ride quality, or structures.

Light intratheatre transport

Our tactical airlift mission is currently being accomplished by the C-130s, C-123s, and C-7s. The C-130s are restricted to conventional take-off and landing operations on moderate length runways. The C-123s and C-7s are limited in numbers, cargo compartment size, and payload capacity.

To provide an improved tactical airlift capability the Air Force is proposing the development of the Light Intratheatre Transport (LIT). We must determine whether this aircraft should have a vertical take-off capability or only a short take-off and landing or STOL capability.

As an initial step in the LIT development, a propeller demonstration program has been started to verify the technology associated with a large diameter propeller. We plan concurrent efforts in the technology of flight controls and engines. When funding is available, we will initiate a competitive design/validation effort by two contractors, leading to the final design. A deliberate development pace will be followed until we are confident that full-scale development and acquisition should commence.

It is clear that the United States is no longer a leader in the world with respect to application of V/STOL technology. Although we have spent over $500 million on 18 different V/STOL systems, none have yet reached the operational stage and at this time our efforts are funded at a very low level.

Most of the work to date has proven that various concepts will work: tilt wing, tilt duct propeller, direct lift, tilt rotor, and lift fan aircraft have all flown. But, in each of these programs, problems have developed which have not yet been solved. Several research aircraft are still being flown by NASA—the X-14, the XV-5, the XV-6, and the XC-142. It is very important that these tests continue in such areas as vibration, downwash, and recirculation investigations; descent and terminal area work; and flow field determinations.

We intend to call on NASA for assistance in analyzing candidates for the Light Intratheatre Transport mission and for continued development in critical areas.

As we all know, NASA has been very successful with its launch vehicle and spacecraft development programs. It may be that NASA should also undertake aircraft development programs in selected areas such as V/STOL, areas that are important to both civil and military capabilities.

The A-X close support aircraft

Providing the best possible close air support for our highly mobile Army units has become increasingly important. Recognizing the need to improve close air support the Air Force is proposing the development of a specialized Close Air Support aircraft called the A-X. It is our belief that an aircraft optimized for the single mission of supporting friendly ground forces will be more effective than a modified or multi-purpose aircraft.

The A-X will be a single seat aircraft of rugged construction. The high thrust-to-weight ratio combined with low wing loading will permit heavy combat loads with short take-off distances and also will produce unsurpassed maneuverability at speeds up to 300 knots. The A-X will be able to provide day and night visual, close-in support to ground troops engaged with the enemy under low ceilings and rugged terrain where high performance jet aircraft cannot operate. The A-X will be the first aircraft with a primary design objective of high survivability.

We expect few technical problems with the A-X, since it will have conventional structure, engines requiring little development, and a minimum avionics pack-

age. However, because of the high thrust-to-weight ratio, problems of low speed stability and performance may arise. NASA assistance may prove beneficial in verifying stability and control characteristics.

New technology

Many technological efforts must be simultaneously advanced in order to realise substantial progress in military aircraft design and the resulting improvements in operational capability. Long before new aircraft can be developed and introduced into the operational inventory, the technical base must be firmly laid by pure research and exploratory and advanced development programs. While recognising that technological advances must be made on a broad front, I shall suggest a few selected concepts and technologies which promise significant gains in the relatively near term: the NASA supercritical airfoil; airload alleviation and mode-stabilization systems: fly-by-wire flight controls; advanced structures such as beryllium and composites of boron and graphite; and, perhaps most important of all, the continuing requirement for advanced aerodynamic and structural analysis methods for system optimization.

One research area in which the Air Force would especially appreciate additional work by NASA is in development of techniques for transonic flight analysis. Improvements in the analytical, wind tunnel, and flight test techniques of evaluating the extremely complex problems associated with flight in the transonic regime would result in major improvements to future fighter, bomber and cargo military aircraft.

Development of the NASA supercritical wing, which will be tested soon on a modified Navy F–8 jet fighter, offers considerable promise for improving cruise efficiency at high subsonic speeds. This concept should be followed by an investigation of new wing shapes and new aircraft configurations to improve the transonic maneuverability as well as the cruise performance. From a military point of view, aircraft maneuverability in the transonic speed flight regime, including target tracking without the presence of airframe buffet, is a very important tactical consideration. The Air Force would like to see NASA test a supercritical wing design on a swing-wing F–111 in order to determine the ability of this aerodynamic shape to improve the transonic maneuver capability as well as delay the drag divergence Mach number. Joint NASA, Air Force and contractor studies for such a program are underway.

Other research efforts which are important to the Air Force deal with the problems associated with aft-end engine nozzle design and airframe wing integration for minimum drag. These difficult design problems are often solved by empirical methods of build-and-try. We need research programs to discover analytical and wind-tunnel solutions. Similarly, we need more knowledge on how to test scaled engine inlet configurations for engine-airframe compatibility. Here again, we have often had to do full-scale engine inlet testing because we don't fully understand both the steady state and pulsative nature of inlet flow.

There has been a continuing trend away from experimental research aircraft in the past several years. We all recognize the high cost of these programs—but we should also recognize the higher cost of changes and delays which may result from the use of unproven technologies.

Research aircraft provide the necessary confidence in new technologies which, with the great expense and complexity of modern aircraft systems, is necessary before the engineering development and production programs can be approved. Flight testing of research vehicles often is the only effective means of fully assessing the value of a potential technological advancement.

The X–15 is an excellent example of the value of experimental research aircraft in advancing the state of the aerodynamic science. Its formal objectives were to investigate flight at hypersonic Mach numbers and at altitudes of several hundred thousand feet, but Dr. Hugh Dryden very succinctly described the underlying purpose of this program as, ". . . exploration to separate the real from the imagined problems, and to make known the overlooked and the unexpected problems."

In design and intial experiment, the X–15 was oriented toward high altitude flight. As the program progressed, the requirement to more fully understand the hypersonic aerodynamic flow field and the structural dispersion of aerodynamic heating became increasingly important. There was a continuous cycle of knowledge gained leading to new questions to be answered. Neither analysis nor ground test could have accomplished the catalyst-like effects of the actual flights. With-

out detracting from the necessity of analytical and ground investigations of complex problems, they simply cannot fully predict the response of an aircraft in flight. You can work out many problems in a wind tunnel, but the wind tunnel remains essentially a simulator. The results must be confirmed in actual flight.

In an effort to provide for flight research up to speeds of Mach 3, the Air Force and NASA have concluded an agreement for a four-year joint program of flight tests on two YF–12s. NASA, with assistance from the Air Force, will use the aircraft to investigate the adequacy of analytical simulation techniques for predicting propulsion system dynamic characteristics, aerothermoelastic effects on aircraft stability and control, and other phenomena associated with cruising flight at Mach 3. The Air Force will also use the aircraft in a modern command, control and electronic countermeasure environment. The YF–12 is an example of a program oriented to NASA research objectives and at the same time used to satisfy Air Force test and operational evaluation requirements.

The Air Force is also interested in other areas of aeronautical research such as air traffic control. This is another field in which both military and civilian aviation will benefit from new developments.

With respect to vertical flight, in 1967 the President's Scientific Advisory Committee recommended the development of take-off and landing systems to assist the pilot in making safe and quick landings under all weather conditions. These would be accomplished in a manner similar to that which the astronauts used in landing on the moon. NASA is currently conducting tests in pursuit of this goal using the inertial system from a Gemini capsule installed in a helicopter.

This research work should be expanded to deal with all types of aircraft and all phases of air traffic control, from take-off to landing.

Air Force exploratory development

The total planned Air Force Exploratory Development program for FY 70 is approximately $240 million, of which about one-half is being applied to technology associated with aeronautical systems and equipment. The bulk of our Exploratory Development or applied research on aeronautics is concerned with flight dynamics, propulsion and materials, along with related work in avionics and the environmental sciences.

In the flight dynamics activity managed by the Flight Dynamics Laboratory, we are working in the five technical areas of structures, flight control, flight mechanics, dynamics and vehicle equipment. Our current efforts are concentrated on reducing the weight and vulnerability of aircraft structures, improving flight control system performance, increasing aerodynamic performance at transonic speeds and improving vehicle equipments such as landing gear and escape systems.

Our propulsion work, managed by the Air Force Aero Propulsion Laboratory, develops propulsion components and technology involving fuels and lubricants, gas turbines, ram-jets and secondary power generation. The primary emphasis is to improve fuel consumption, thrust-to-weight ratios and thrust-to-frontal area ratios.

The materials effort, managed by the Air Force Materials Laboratory, is centered on the development of high temperature metal alloys for jet engines and the application of composite materials for aircraft structures. The work in high temperature metal alloys is directed toward improving the strength and temperature properties of these materials. Composite materials are being developed that pomise to reduce the structural weight of future aircraft by 50%. This new technology has been successfully used to achieve a 65% weight reduction in the horizontal stabilizer skin and consequently an overall weight reduction of 27% in the stabilizer of the F–111 aircraft.

In the environmental sciences we are investigating the properties of the atmosphere in such areas as clear air turbulence, weather forecasting and weather modification as they apply to aeronautics.

Air Force advanced development

The total planned Air Force Advanced Development Program for FY 70 is approximately $400 million of which about $60 million is being applied to Aeronautics. In addition to advanced development work oriented to specific aircraft systems, the Air Force also conducts technology programs that will provide a diversified technology base for future systems as they become better defined.

In the propulsion area we use the technology and individual components from our exploratory development program and integrate them into advanced propulsion systems. These new propulsion systems are integrated with the air-

frame and tested in our advanced development program called Aircraft Propulsion Subsystem Integration.

The Aerospace Structure Materials Program uses technology from our exploratory development materials program to fabricate aircraft components from the composite materials and to flight test these components under operational conditions.

Other advanced development programs include the fabrication and testing of flight controls for improved survivability under the Flight Vehicle Subsystems Program and the collection of data relative to the National Clear Air Turbulence Program.

Funding for new aircraft programs

For the F-15, $77.5 million was programmed through FY 69, and $175.1 million has been authorized for FY 70.

The B-1 program received $143.8 million through FY 69, and has been authorized $100.2 million for FY 70.

Less than $1 million was allotted to the A-X through FY 69, and $8 million has been authorized for FY 70. We hope for an appropriation of at least $2 million to initiate competitive prototype development.

The Light Intratheatre Transport received $1 million through FY 69. No money was authorized for FY 70, but related technology programs amount to $3.6 million.

Secretary SEAMANS. Mr. Chairman, members of the subcommittee, I am very happy to have a chance to appear here with you today, to discuss aeronautical research, because it is of such importance to the Air Force at this time. I believe that I would like to proceed through my statement, and perhaps there are places where I can summarize it in order to save time.

Mr. HECHLER. You may proceed, Mr. Secretary.

Secretary SEAMANS. The subject of aeronautical research is of primary importance to the Air Force. We have good aircraft, but many of them are now getting old and may soon be obsolete.

Our best air-to-air fighter, the F-4, first flew in 1958. It is still in a class with the Mig-21, but the Soviets displayed six new fighters at their air show on July 1967, raising serious questions about our relative capability in coming years.

In the area of strategic bombers, our B-52 first flew in 1952, coincidentally, and the last aircraft was produced in 1962. In the meantime, aeronautical technology has advanced a considerable distance, and Soviet air defenses have greatly improved.

If we are to maintain an adequate Air Force, we must continually press forward with our aeronautical research and aircraft development programs. In this process, cooperation between NASA and the Air Force is a critical factor.

I might say now in summary of the section on the F-15 air-to-air fighters, where the complete statement might be placed in the record, that we have received a considerable amount of help from NASA at all stages in the F-15 procurement. We now are at a point where we have had submittals from three contractors to proceed with, first, the development and then the procurement of about 750 of these aircraft. NASA has helped us in the past and is helping us today to evaluate these proposals and it is our intention to select a contractor and then proceed immediately with the development of the airplane.

I will just read the last paragraph.

NASA direct support of contractors is critically important to the success of our development efforts. We must determine how well configurations work over wide speed and altitude ranges. Contractors

have some wind tunnels and have access to the Cornell Aeronautical Laboratory and Air Force laboratories, but much of their work must be done at NASA labs. This should be considered essential R. & D. assistance and should be funded accordingly.

And I can say here that there has been a limitation on NASA's ability to support aeronautical contractors, not just in this program, but in other Air Force and Navy programs. When it was all added up there was a greater demand for wind tunnel time than could be supplied by NASA, in view of limitations imposed on them by what in the past at least was called their administrative operation funding. This was specifically a limitation on the technicians available to run the wind tunnels. This forced the wind tunnels to work on less, I believe, even, than an 8-hour shift. It certainly did not permit them any great flexibility to operate overtime.

Mr. HECHLER. This was specifically limitation on personnel, in administrative operations? Or did it go beyond that?

Secretary SEAMANS. It was both a limitation on personnel funding and on funding for such things as electricity to operate the wind tunnels, according to my understanding.

Mr. HECHLER. I think it would be helpful to tie that down for the record.

Secretary SEAMANS. I would be happy to supply more details for the record.

Mr. HECHLER. Yes.

(More details for the record is as follows:)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, D.C., December 23, 1969.

To: Colonel W. B. Arnold, SAFLLV, Room 5D-920, The Pentagon, Washington, D.C. 20330.

From: Deputy Associate Administrator (Aeronautics), Office of Advanced Research and Technology.

Subject: Transmittal of information on NASA support of DOD aeronautical contractors.

In response to your request, the following statement is supplied with respect to NASA wind-tunnel support of DOD aircraft development programs.

A continuing function of the NASA program in aeronautics is to provide experimental aerodynamic data from its unique large-scale wind-tunnel facilities to contractors of the military services for new aircraft and missile systems. This assistance when requested by the service and determined to be required is furnished without direct transfer of funds. The costs are covered by NASA Center Research and Program Management (R&PM) funds, formerly designated administrative operation (AO) funds, which pay for salaries and most expenses as well as the facility electric power for the tests.

Thus limitations on R&PM funding and personnel imposed upon the Centers do limit the wind-tunnel support NASA is able to provide to the Department of Defense. With additional R&PM funding it would be possible to buy additional electrical power so that the wind tunnels could be operated more shifts per day than at present. However, to operate substantially more would require increased personnel to man the extra shifts and to conduct the larger number of investigations undertaken. The increased personnel would, of course, increase further the need for R&PM funding.

For example, the attached table indicates the extent to which it would be feasible and desirable to increase the utilization of those facilities of the NASA Langley Research Center in greatest demand by the DOD services and other government agencies, assuming present funding and personnel constraints were relieved. It is seen that the three wind tunnels representative of the largest capital investments were operated during the last fiscal year at only half to two-thirds of their capacity.

A similar situation exists for the large wind tunnels in greatest demand for support of other government organizations at the NASA Ames Research Center. In FY 1969 approximately half of the available wind-tunnel time at Ames was given over to developmental tests requested by the Air Force, Navy, or Army. The 40- by 80-foot wind tunnel was operated full time for two shifts per day; it would have been feasible and desirable to have operated on a three-shift basis inasmuch as there now exists a two-year backlog of work for this one-of-a-kind facility. The three "Unitary Plan" wind tunnels—11-foot transonic, 9- by 7-foot supersonic, and 8- by 7-foot supersonic—were used together for 4520 hours during the year or something over two shifts per day. This was accomplished by working available personnel overtime and bringing in additional personnel from other facilities, As a result, planned utilization of other smaller facilities had to be reduced by 67 percent. As at Langley, under the existing manpower and funding limitations the support of aerodynamic testing requirements of other Government agencies was supplied at the expense of in-house research activity.

Under the circumstances the NASA Centers can only supply full support for the most urgent of specific requests for use of their facilities from the other Government organizations. All such requests from organizations of the Department of Defense during FY 1969 and previous years are believed to have been properly satisfied. In each case adequate test programs and facility schedules were determined at the Center by matching the contractor's proposed requirements against available NASA research information and facility time that could be made available. With the country essentially at war, no reasonable demand could be refused, however the assistance was often provided at the expense of in-house general research which is vital to the advancement of the nation's aeronautical technology and capabilities. On the other hand it is likely that other valid needs for NASA facility utilization were not pressed by the military services because of their awareness of the resources limitations at the Centers, and that the definitive answer as to the adequacy of the NASA wind tunnel support might come from DOD sources.

CHARLES W. HARPER.

Attachment.

[ATTACHMENT]

Langley facilities in greatest demand for research support of other Government organizations	Facility cost, accumulated to present time (thousands)	Fiscal year 1969 operation (shifts per day)	Feasible operation (shifts per day)
Unitary plan wind tunnel	$15,620	2	3
16-foot transonic tunnel	12,867	2	3
8-foot transonic pressure tunnel	7,061	2	3
Transonic dynamics tunnel	11,184	1⅓	3
High-speed, 7- by 10-foot tunnel	2,907	1	2
300-mile-per-hour, 7- by 10-foot tunnel	704	1	3
4-foot supersonic pressure tunnel	3,441	1	2
Full-scale tunnel	1,252	1⅓	3
Spin tunnel	103	1	2
Landing loads track	4,487	1	2

Secretary SEAMANS. Now turning to the B-1 strategic bomber, again let me say in summary that we in the Air Force and in the Department of Defense believe that the time has come when we should develop a new bomber system. As I have already said, the B-52 has served us well for nearly 20 years. We believe that we need a new manned aircraft to provide capability for the strategic mission, and we also note that a manned bomber can have uses other than those originally intended. This is well exemplified by the performance of the B-52's in Southeast Asia today.

We have just recently gone out with a request for proposal. There are four companies that have indicated their interest and their intent to propose. NASA is again supporting our program, and this is needed in many areas. We hope to use the expertise of six to 10 NASA personnel as part of the source selection teams. Subsequent to source se-

lection, continual liaison will be maintained with NASA so that their expertise can be used should any problems develop in internal or external aerodynamics, aircraft handling, stability, ride quality, or structures.

Now turning to light intratheater transportation.

I have been to Southeast Asia to see how our C–130's, C–123's, and C–7's have been operating, and they have been doing an excellent job. There are times when even with our C–7's we can not get into an airport. In those cases we have two choices. We can either use airdrop, which on occasion puts the aircraft under intense fire, or we can use helicopters.

Helicopters in general are limited by their weight-carrying capability. There has been a considerable amount of effort, as this committee is well aware, in the direction of vertical and short takeoff landing aircraft, and the question is still before us whether we should embark on a development with such an objective.

Mr. HECHLER. Excuse me, Mr. Secretary. Off the record.

(Discussion off the record.)

Mr. HECHLER. The committee will be in recess for 15 minutes.

(Whereupon, a recess was had.)

Mr. HECHLER. The committee will be in order.

Secretary Seamans, you may proceed.

Secretary SEAMANS. Mr. Chairman, I was referring to short takeoff and landing aircraft and vertical takeoff and landing aircraft, and I was just pointing out that we must determine whether these aircraft should really have a true vertical takeoff capability, or whether it is sufficient just to have excellent short takeoff and landing capabilities.

Most of our work to date has proven that various cruise concepts will work, tilt wing, tilt duct prop, direct lift, tilt rotor and lift fan aircraft have all flown, but in each of these programs problems have developed which have not yet been solved. Several research aircraft are still being flown by NASA, the X–14, the XV–5, the XV–6 and the XC–142.

Now we in the Air Force have some real questions about V/STOL aircraft. In theory they are highly desirable for the reasons I mentioned earlier, but we are concerned that the percentage use in the vertical mode might be rather small, and then every time we take off in the STOL mode we would be increasing weight unnecessarily and adding complexity and these aircraft must be extremely rugged to operate in the kinds of conditions that we now have in Southeast Asia.

As we all know, NASA has been very successful with its launch vehicle and space travel development programs. It may be that NASA should also undertake aircraft development programs in selected areas such as V/STOL in order to prove concepts for both civilian and military use.

Now continuing on page 6, a few words about our AX close support aircraft.

In this case we are talking about an aircraft that in effect would live with the Army. It would have to be rugged, it would have to operate out of short fields. It would have to be very survivable under fire. It would have to have considerable firepower, to permit it to directly support the Army.

We are considering, in this procurement, having a minimum, if you will, of detail in the proposal effort. In effect we would end up with two companies, each one of which would build a prototype, we would have a true flyoff and determine on that basis which aircraft performed the best.

Now, we also have underway in the Air Force many technological efforts. We believe these must be simultaneously advanced in order to realize substantial progress in military aircraft design and the resulting improvements in operational capabilities. At the bottom of page 8 I note that one research area in which the Air Force would especially appreciate additional work by NASA is in development of techniques for transonic flight analysis. Improvements in the analytical, wind tunnel, and flight test techniques of evaluating the extremely complex problems associated with flight in the transonic regime would result in major improvements to future fighter, bomber, and cargo military aircraft.

Other research efforts which are important to the Air Force deal with the problems associated with aft-end engine nozzle design and airframe wing integration for minimum drag. These difficult design problems are often solved by empirical methods of build-and-try. We need research programs to discover analytical and wind-tunnel solutions. Similarly, we need more knowledge on how to test scaled engine inlet configurations for engine-airframe compatibility.

There has been a continuing trend away from experimental research aircraft in the past several years.

Research aircraft provide the necessary confidence in new technologies which, with the great expense and complexity of modern aircraft systems, is necessary before the engineering development and production programs can be approved.

The F-15 is an excellent example of the value of experimental research aircraft in advancing the state of the aerodynamic science.

In the design of the F-15 even though we have a very good supersonic capability, much of the aircraft's actual fighting may be done in the transonic region.

One of the things we are concerned about in the F-15 is the inlet problem at large angles of attack, in a maneuver to bring the aircraft around to attack another fighter. It is at these sort of off nominal conditions that we may run into very difficult inlet problems.

I don't think I need to tell this committee about the flights of the F-15, the fact that it has flown faster and higher than any other airplane. We have gathered a great deal of important aeronautical information and also had a test bed which was very useful for other purposes. We are delighted that the Air Force has now worked out with NASA a program to use the two YF-12's for a continuing flight research program, with the capability of speeds up to mach 3.

In addition to work on airframes, propulsion and so on, the Air Force is also interested in other areas of aeronautical research such as air traffic control. This is another field in which both military and civilian aviation will benefit from new developments.

NASA is currently conducting tests in pursuit of this goal, and I believe Mr. Elms discussed this with your committee.

This research work, we believe, should be expanded to deal with

all types of aircraft and all phases of air traffic control from takeoff to landing.

Now, just to summarize our total aeronautics program, we have, first, the Air Force exploratory development. Our total exploratory program for 1970 is approximately $240 million of which about one-half is being applied to technology associated with aeronautical systems and equipment. We have an Air Force advanced development program which is described starting on page 15. Here the total planned Air Force advanced development program for fiscal year 1970 is approximately $400 million of which about $60 million is being applied to aeronautics.

We also have in our research and development area funding for our new aircraft. I have already mentioned the F–15. We have $175 million authorized for 1970. For the B–1 bomber program, we have been authorized a little over $100 million. We have $8 million authorized for the AX close support aircraft. And actually no money except in the advance technology area for the light intratheater transport. If you add all of this up, it comes to $468 million of research and development. Yon can see how important the field of aeronautics is just from a development standpoint. I don't have the number right at my fingertips, but the aircraft procurement for fiscal year 70 runs to about $4 billion, so that the more basic work that NASA does leads to specific developments of major proportion which, in turn, of course, influence our success in these very large procurements.

So that completes my statement for the morning, Mr. Chairman.

Mr. HECHLER. Thank you, Mr. Secretary.

You have confined most of your remarks to the importance of aeronautical research, and its relation to the Air Force. As one who has held a high position in NASA, and has been very active in many phases of aeronautical development over the years, just how would you weigh and assess, in a brief statement, the importance of aeronautics in the Nation, across the board?

Secretary SEAMANS. Well, across the board, there isn't any question about its importance to the Nation and to the world. The world has truly shrunk by virtue of the field of aviation. The number of passengers flying daily for long distances is truly remarkable, even viewed today, much less if it had been viewed and understood 10 or 20 years ago.

Clearly, in the commercial field, I think this was stressed by Dr. Foster, our aeronautics effort is one of the shining lights of our situation. We are selling aircraft all over the world because we have had preeminence in this field.

It is a question of whether we are going to maintain this superiority in the future, and that is the reason the research and development today in aeronautics is so important from a commercial standpoint.

From the standpoint of the military, it is obvious that aeronautics is extremely important. There has been for a period of time sort of a swinging of the pendulum toward missiles and toward space. I think it was appropriate at that time.

I think now our need in the Air Force, as well as in the Navy, for some new aircraft is apparent, and I think this comes at a very fortuitous time, because as a result of our missile and space work, we have some new capabilities that we can now bring to bear.

So I assess the field of aviation as one of the most important fields in this country today.

Mr. HECHLER. I fully concur with what you have just said. You cited some examples, and other witnesses before this committee have cited the frustrations because we have many different V/STOL systems and techniques that have been developed, yet none of them far enough along so that we can put them into full operation for both civilian and military use.

This is only one small piece of the problem, though, but it is illustrative of what I believe is needed—namely, a precise statement of goals and priorities at the highest national level.

If such a statement were promulgated and decisions were made, don't you believe that this would help achieve the objectives that you are seeking? This would relate the importance of aeronautics to the development of our Nation.

Secretary SEAMANS. Yes; I think it would, and I think this ties in with a statement I made when I appeared before Congressman Daddario's committee on the goals of this country and the relationship between research and development and the attainment of these goals.

And clearly, one of the major important areas for attention is in transportation, broadly speaking—ground, sea, and air—and there are some real problems that we face in aeronautics, as we all kr...

Even though we have made great advances in the development .. the airplane itself, we still have very, very difficult problems to face up to, which we haven't really faced up to in air traffic control, traffic handling at the terminals and so on.

I think a statement of this is a national necessity, and then the followup of the related work would be helpful.

Mr. HECHLER. Mr. Wydler.

Mr. WYDLER. Doctor, do you find any problem with this new section 203 that has been discussed here, in relation to your program?

Secretary SEAMANS. I was very interested in the discussion you had with Dr. Foster. He is, from the Defense standpoint, our leader in this matter. We in the Air Force are doing exactly what he has described for the Defense Department as a whole.

We are going back and going over all of our programs again, both from the standpoint of the budget reduction which we have sustained, as well as from the standpoint of whether there is a clear application of the work to either our equipment of our operations.

And I can give you an example of where there is a problem. It is not really an aeronautical matter. I don't have one of those at my fingertips. But there is at M.I.T. a national magnets laboratory that has been funded by the Air Force. It is in the budget for about $2.6 million this year.

It is a laboratory that has done very outstanding research in connection with a large number of research people who come and use this facility, some of whom have actual Air Force experiments—and others who have experiments sponsored by different agencies.

The question arises now whether we can justify in the future the full support of that lab, and we have just got to take a hardheaded view, because we must comply with this 203 amendment.

Mr. WYDLER. It seems ironical that it should strike the civilian sector of the research field, particularly for the sponsors and pro-

ponents of the amendment, anyway. But I don't want to comment on that.

The F-15, for example. Can that have any possible civilian use that you can think of?

Secretary SEAMANS. I doubt that the airplane as a complete system has direct civilian application.

Mr. WYDLER. You think there might be some fallout in equipment?

Secretary SEAMANS. I believe that in every major aircraft development there is fallout from materials, propulsion, flight control, instrumentation, that does become generally available to the indsutry, and does find its way into a civilian use.

Mr. WYDLER. How about this B-1 program? Can you give me an idea what type of—is there such a thing as a specification?

Secretary SEAMANS. Yes.

Mr. WYDLER. How many motors does this plane have?

Secretary SEAMANS. I believe this is one of the items that will be proposed by the competitors. I believe, though, it will have four engines.

The features of the airplane that differentiate it from, say, the B-52, are first of all survivability. The B-52 does take special runways. The new plane will have a capability of using much shorter runways. It can, for that reason, be dispersed more widely.

It will also be designed so that from the clang of the klaxon, it can get off the runway in a much shorter period of time, which leads to survivability.

And it will also be designed for larger overpressure, so that it can even be reasonably close to a nuclear explosion and still get out and carry out its mission.

Mr. WYDLER. Will it look like or be similar to the proposed SST in any way?

Secretary SEAMANS. Well, this is one of the items that is still in question, whether it will actually be a fixed wing or a variable sweep wing aircraft. We want the contractors who are proposing to give us trade offs on this.

It will have, at high altitude, some supersonic capability, but the reason for that is not that that, per se, is as high priority as the low-altitude penetration capability, which we want to be high subsonic, even under adverse conditions of weather.

So it must have very good ride capability at low altitude, and once you put in this requirement, it is not much more expensive to provide the high-altitude supersonic capability.

Mr. WYDLER. That's all.

Mr. HECHLER. Mr. Goldwater.

Mr. GOLDWATER. I have no questions.

Mr. HECHLER. If there are no further questions, I want to thank you, Mr. Secretary, for this extremely helpful testimony.

And if there are no further questions, these hearings are concluded.

I would like to thank the members of the subcommittee, the chairman of the full committee, Mr. Miller, who authorized these hearings, the members of the staff, the excellent witnesses and all others who participated in making these hearings a success. I am convinced that we have taken a number of forward steps in focusing attention on

the vital area of aeronautics and its importance with relation to the present and future strength of the Nation.

(Whereupon the subcommittee was adjourned).

In addition, various agencies and organizations were asked to make recommendations to the subcommittee giving their views on additional R. & D. needs of the Nation. These submissions follow:

AIRCRAFT OWNERS AND PILOTS ASSOCIATION,
Washington, D.C., December 18, 1969.

Mr. KEN HECHLER,
Chairman, Subcommittee on Advanced Research and Technology, Committee on Science and Astronautics, U.S. House of Representatives, Washington, D.C.

DEAR MR. HECHLER: AOPA appreciates your kind invitation of December 11, 1969 to submit comments regarding aeronautical research and development. Due to the brief time remaining for inclusion in the record, we will confine our comments to a few things which seem most important.

We have reviewed our submission last year (Aeronautical Research and Development, Hearings before the Subcommittee on Advanced Research and Technology of the Committee on Science and Astronautics, 90th Congress, 2nd Session, Vol. 10, page 320) and find little that needs change. The problems enumerated still remain.

The rate of growth of general aviation has been retarded by inflation, restrictive regulations and the imminence of selective taxation. The attached table gives some comparative data for the last two complete years. Note that the items of growth (issuances, unit sales) barely held over or are negative. Average unit cost has soared. Indications in 1969 are that student starts are still declining, unit aircraft sales are down though dollar volume is up, and operations at many airports have suffered a decline.

The implications for the economy are clear. Small communities depend upon general aviation for access to the benefits of air commerce. Industry relies upon it to operate widely dispersed plants. Recreational enterprises use it to survive. Business employs it for sales and service. Strenuous efforts are needed to make general aviation more useful and less expensive as well as safer, if it is to perform its essential role.

General aviation accounts for 98% of the civil aircraft, 97% of the pilots, 94% of the airports, 82% of the hours flown, 75% of the operations at tower controlled fields and virtually 100% at the other 10,000 landing places in the nation. It is a substantial and important part of "civil aeronautics".

It, therefore, seems just a little odd that of the $77,700,000 authorized for aeronautical research in the NASA program for FY 1970, only $500,000 or less than 1% was allocated for research directly related to general aviation. We urge the committee to remedy the imbalance of this relationship.

After watching the research and development efforts of the Federal Aviation Administration and its predecessors for some 30 years, it appears to us that the same amounts of money would have yielded many more useful results if someone else had had the responsibility for programing and expenditure. At the same time, we are not satisfied with the attention and treatment that aeronautics gets within the structure of NASA where the space program is so predominant.

For these reasons we urge the committee to consider combining the research and development program of the FAA and the aeronautics program of the NASA into a new and separate Aviation Research and Development Agency with an enlarged mandate to support basic and applied research and prototype development for all aviation purposes.

It is our hope that such an organization could then fill some of the existing gaps, referred to in our statement last year, which preclude the economic production of more useful and efficient aeronautical vehicles, which delay the development of an adequate air traffic system that satisfies all user requirements rather than only a small percentage of them, and which result from omission of the human factor considerations that affect the safety and utility of aviation operations.

Federal aviation research and development efforts lack adequate liaison with the ultimate users of the products of those efforts. A continuing program to

assure adequate user input is needed. Regular contact only with producers' representatives or FAA officials is not/sufficient. The consumer needs and wants direct consultation to assure that his requirements, not those imagined for him by others, are considered.

We appreciate your consideration of these and previous comments.

Cordially,

ROBERT E. MONROE,
Congressional Liaison.

Item	1968	1967	Difference	Percent
Airports	$10,470	$10,127	+$343	+3
FAAP airports	$2,307	$2,257	+$50	+2
Active aircraft	$124,237	$114,186	+$10,051	+9
Active pilots	$691,695	$617,931	+$73,764	+12
Instrument ratings issued	17,972	19,255	−1,283	−7
Pilot certificates issued	228,374	241,526	−13,155	−5
Additional ratings issued	34,751	35,146	−395	−1
Student issuances	149,444	159,399	−9,955	−6
General aviation:				
Hours flown	24,053,000	22,153,000	+1,900,000	+9
Airplane shipments:				
Number	13,749	13,536	+213	+2
Value	$553,184,000	$410,387,000	+$142,797,000	+35
Average unit cost	40,235	30,318	+9,917	+33
General aviation accidents	[1] 4,968	6,115	−1,147	−19
Fatalities	1,399	1,228	+171	+14
Fatalities per 100,000 hours	5.8	5.5	+.3	+5

[1] Not comparative—criteria changed so fewer accidents reported.

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